Variation in Bird Diversity with Habitat Quality in Hobart, Tasmania

by Megan Heileman BA.
University of Tasmania

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Declaration

This thesis contains no material which has been accepted for the award of any other degree or diploma in any tertiary institution, and to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

Signed

Megan Heileman BA.

Photograph on cover page: Green Rosella foraging on Banksia, University of Tasmania campus, Sandy Bay.

–Megan Heileman

Abstract

As urban areas expand throughout the world, they have a number of negative impacts on native wildlife. Birds are a useful indicator group for measuring such impacts. This study aims to assess urban impacts on birds, assessing bird diversity, abundance and species composition across a range of urban environments, from the city centre to native vegetation remnants. Particular emphasis is placed on the potential conservation value of urban parks and native vegetation remnants, and on habitat quality factors determining variation in native bird diversity, including measures of vegetation, invertebrates and human disturbance levels. It is hypothesized that native bird diversity and abundance will decrease with decreasing habitat quality.

Birds were surveyed six times over nine weeks in summer and autumn, 2007, in Hobart, Tasmania, using the rolling point count method. Surveys took place at five urban sites including Hobart city centre, a residential area (Sandy Bay), three native vegetation remnants (Queen's Domain, Bicentennial Park and Knocklofty Reserve). Data was also collected on plant species, vegetation structure, invertebrate species on plants and human disturbance including percent cover of built environment, vehicle traffic, pedestrian traffic and noise levels at the point counts. Statistical methods used included bar charts of species richness and abundance, ordinations of species, species classifications, one tailed t-tests and correlation analysis between habitat variables and bird species richness. PC Ord 4 was used for ordinations, Minitab for the correlation analysis and Excel for all other analyses.

Results of this study show that native bird species richness and abundance is significantly higher in the native vegetation remnant sites than in the urban sites, urban parks have more native species than surrounding streets and the city centre has fewer native bird species than the residential site. Abundance was highest at Knocklofty, followed by the two urban sites but the majority of the urban abundance composed of introduced species. Bird species composition was similar in the native sites and in the urban sites but native and urban sites were very different from each other. The same was found to be true in the case of plants. Also, native birds correlated positively with native plants, vegetation cover and complexity. Likewise, introduced birds correlated positively with introduced plants. Bird behavioural interactions were found to reinforce these trends. Invertebrate species richness and abundance was not significantly different at urban sites than at native sites. Invertebrate species composition did vary, however,

loosely on the basis of site and plant species they were found on. This and seasonal variation in abundance of invertebrates could have important implications for birds. Human disturbance variables were significantly negatively correlated with most native bird species, and positively correlated with introduced species. Season also played a role in variations in native bird species richness and abundance, as many species favoured summer, particularly summer migrants, and a few favoured autumn or were season neutral.

The results of this and other studies suggest that the maintenance of native vegetation remnants is essential to maintaining a high native bird species richness and abundance, but that urban parks and gardens improve landscape connectivity and can act as supplementary resources for native birds, especially during winter. Also, both habitat quantity and quality are important for the long term sustenance of diverse native bird communities in an urban setting.

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Chapter 1 Introduction

1.1 Urbanization and its effects on wildlife

1.1.1 Global and Australian national trends

Urban populations have increased rapidly since 1900. The world's urban population grew from 220 million people in 1900 to 3.2 billion in 2005, an almost fifteen-fold increase in just over a hundred years. This number is projected to increase to almost 5 billion by 2030, with the most rapid growth occurring in the developing world. Almost 50% of the world's population now lives in urban areas, up from 13% in 1900 and projected to rise to 60% by 2030. In the developed world, almost three quarters of the population lives in urban areas (United Nations, 2005).

Cities of the world have expanded in size as well as number. Although 51% of the world's urban dwellers still live in cities of under 500,000 people, the number of cities with populations of over 10 million has increased from one in 1940 to 20 in 2005. Furthermore, a tendency towards decentralization and urban sprawl has led an even greater expansion of urban land area than is strictly explained by population growth (Hartog, 1999).

Australia is one of the most urbanized countries in the world with 63% of the population living in its major capital cities and another 22% living in smaller cities and towns (Kalma and Flemming, 1995). Currently, most of the population growth, which is projected to reach 23 million by 2021, is taking place in the major cities, especially in the suburbs (Department of the Environment and Water Resources, 2006).

1.1.2 Effects on wildlife

Human activities, including urbanization, have had widespread impacts on wildlife. Extinction rates are up to 1,000 times higher due to human impact than the normal background extinction rate (indicated by fossil records) (Baillie *et al.*, 2005). There have been 784 species documented extinct since 1500 A.D. and another 60 species are extinct in the wild. Another 15,589 species are documented as threatened with extinction including 12% of the world's birds, 23% of the world's mammals and 32% of amphibians (Baillie *et al.*, 2005).

Effects of urbanization on wildlife include habitat loss and fragmentation, introduction of weeds and domestic and feral animals, air and water pollution, changes in fire regime, erosion and cultural eutrophication (Bridgman *et al.*, 1995). Habitat loss (including due to fragmentation) and invasive species are the first and second highest causes of extinction globally (Baillie *et al.*, 2005). Habitat fragmentation leads to the formation of small "habitat islands", which are low in biodiversity because of their small size (Macarthur and Wilson, 1967). In addition, habitat islands limit gene flow by limiting animal dispersal throughout the landscape and increase other urban impacts through edge effects (Bridgman *et al.*, 1995). Invasive species displace native species by competition and predation, cause the homogenization of biota and can act as vectors for the spread of disease (Bridgman *et al.*, 1995). Pollution bio-accumulates in the food chain and can cause death and disease especially of the species at the top of the food chain. Changes in fire regime, erosion and eutrophication can effect the regeneration of trees and other vegetation and facilitate invasion by exotic plants, thus altering the remaining habitat available to wildlife in areas adjacent to urban centres (Bridgman *et al.*, 1995).

Nevertheless, despite an increasingly urbanized world and the resulting impacts on wildlife, few studies have been conducted on wildlife in an urban setting compared to those conducted in a natural one (LeFort, 2002; Daniels, 2005). Wildlife response to urbanization is therefore not fully understood. A better understanding of wildlife response to urbanization could aid management decisions to minimize negative impacts and maintain biodiversity of native animals in urban settings. In that spirit, this study aims to improve conservation outcomes for urban wildlife, by adding to the body of knowledge on the impact of urbanization on wildlife, particularly birds.

1.2 Why birds?

Birds serve as good biological indicators of the effects of human disturbance on native wildlife (Sauberer, 2004; Reynaud, 2000) because they respond to secondary changes resulting from primary causes and react rapidly to changes in their habitat due to mobility (Reynaud and Thioulouse, 2000). Birds have been used extensively as indicators in Australia (MacNalley *et al.*, 2004) and abroad (Hutto, 1998; Canturbury *et al.*, 2000). In Britain, they are even used as an indicator of national health alongside GST and employment figures (de Blas, 2001).

Nevertheless, there are some shortcomings in using birds as indicator taxa. Several studies have found that using one indicator group couldn't always predict biodiversity of other groups (Lawler *et al.*, 2003; Schulze *et al.*, 2004), but indicator groups are often still found to be a useful tool to assess animal response to disturbance (Moore, 2003 and Sauberer, 2004). Likewise, using an indicator group such as birds doesn't always predict the response of individual species such as rare or threatened species (Canturbury *et al.*, 2000). However, Hutto (1998) asserts that using a large group such as land birds is still a better representation of all vertebrates than using a few select species. Moore (2003), and Canturbury *et al.* (2000), expressed concern that birds could fail to be reliable indicators due to their high mobility and migration. Canturbury *et al.* (2000), used habitat characteristics in conjunction with bird studies to indicate response to disturbance to overcome this limitation; a factor which is incorporated in this study.

In addition to being useful biological indicators, birds are relatively easy to study. This is due to their conspicuousness (Tuxill and Bright, 1998) resulting from the dawn chorus (Brown and Handford, 2003) and the high number of species which are diurnal. They are also ecologically versatile (Koshkimies, 1989) and have indeed adapted to urban environments to a greater degree than many other taxa. In addition, they are relatively inexpensive to study (Koshkimies, 1989), can be observed with relatively little experience (Hewish and Loyn, 1989) and the large number of species and individuals make them amenable to statistical analysis (White *et al.*, 2005). Finally, there are fewer species of birds worldwide, just 9,040 (Wilson, 1989), than other classes of animals such as insects, which makes them more practical to study (LeFort, 2002).

1.3 Urban bird study types and settings

Urban bird studies have had a variety of different focuses. Some have focused on urban birds in relation to spatial features, both in terms of distance from the city centre (Daniels, 2005) and distance to native vegetation patches (Caterall *et al.*, 1989) while others focused on urban birds in relation to age of suburb (Jones, 1981; Munyenyembe *et al.*, 1989). Some compared various suburbs within a city (Daniels, 2005; Green, 1986) whereas others compared two different cities (Green *et al.*, 1989; Jokimaki *et al.*, 1996; Clergeau *et al.*, 1998). Some compared urban areas and adjacent nature reserves (Wood, 1996; Biessinger and Osborne, 1982) while others compared species richness with native remnant patch size in an urban landscape (Howe, 1986; LeFort, 2002). Many focused on bird response to habitat change across an urban gradient (Blair, 1996; Germaine *et al.*, 1998; White *et al.*, 2005). Others focused on birds in urban gardens (Moverly, 1997; Daniels and Kirkpatrick, 2006) and parks (Blanco, 1996; Cornelis, 2004). Quite a few urban bird studies focused on bird communities in relation to various aspects of habitat quality in an urban setting. These included vegetation species composition (Green, 1986; Catarall, 1989), structure (Biessinger and Osborne, 1982; Munyenyembe *et al.*, 1989; Fernandez-Juricic, 2000a) and volume (Mills, 1989), invertebrates (Green, 1986) and degree of human disturbance (Blair, 1996). This study is an urban gradient study focusing on habitat quality in urban streets, parks and remnant native vegetation reserves. Thus, studies pertinent to this focus will be elaborated on in the following chapter.

Most urban bird studies have taken place in the northern hemisphere (Beissinger and Osborne, 1982; Blair, 1996, Jokimaki *et al.*, 1996; Clergeau *et al.*, 1998; Fernandez-Juricic, 2000a & b). Thus, comparatively little data exists on urban birds in the southern hemisphere. Nevertheless, some research has taken place in Australian cities (Jones, 1981; Catterall *et al.*, 1989; Green *et al.*, 1989; Munyenyembe, 1989; Wood, 1996; Sewell and Catterall, 1998; Daniels and Kirkpatrick, 2006). This study seeks to add to the knowledge attained so far from urban bird studies in an Australian context.

1.4 Aims and scope of study

The aims of this study are as follows:

1. To determine the effect of varying degrees of urbanization on native bird diversity and abundance and on the level of invasion by introduced species.

2. To assess the efficacy of urban parks and native vegetation remnants in maintaining a high native bird diversity and abundance and in reducing invasion by exotic species in the face of urbanization.

3. To determine what aspects of habitat quality including vegetation, invertebrates and degree of human disturbance, are most influential in promoting native bird diversity and abundance and in helping prevent invasion by exotic species.

Thus, bird diversity, abundance and species composition across the urban gradient, including urban streets, urban parks, and remnant native vegetation reserves and habitat data on vegetation, invertebrates and degree of human disturbance will be considered in this study. Aspects of urban bird studies which are beyond the scope of this study include bird density and biomass measurements, distance from city centre or native vegetation, location in the landscape, age of suburb/town, size of habitat remnant and comparison with other towns and suburbs. However, the influence of size of reserves will be discussed in relation to other studies, because it is an important influence on native birds.

1.5 Questions and hypothesis

The following questions will need to be answered to meet the aims of the study:

1. What is the difference in bird diversity, abundance and species composition in a range of urban and urban fringe environments from highly disturbed to relatively undisturbed?

2. Is there a greater diversity and abundance of native birds and fewer exotic birds in urban and/or native vegetation remnant parks than in surrounding urban streetscapes?

3. Does variation in native and exotic bird diversity and abundance correlate strongly with variation in vegetation, invertebrates and/or degree of human disturbance across the range of urban habitats?

The hypothesis is that there will be an inverse relationship between the level of human impact associated with urbanization on the environment and native bird diversity and abundance. Conversely, there will be a direct relationship between the level of human impact on the environment and the abundance of introduced birds. Urban and native vegetation parklands will therefore help to mitigate the negative impacts associated with urbanization on native bird diversity and abundance and help to reduce the invasion of introduced species.

1.6 Thesis structure

Chapter 1 gives an introduction to urbanization, its effects on wildlife and urban bird studies and outlines the study aims, scope, questions and hypothesis.

Chapter 2 provides a background of previous studies on urban birds, urban gradient studies, birds in urban native vegetation remnants and urban parks, and urban birds in relation to habitat quality including plants, invertebrates and human disturbance.

Chapter 3 introduces the five study sites and outlines methods used for bird surveys, gathering environmental data and statistical analysis.

Chapter 4 outlines the results of the data collection in terms of the three questions posed in the introduction, using figures and tables for illustration.

Chapter 5 discusses the results of this study in relation to the questions posed and to the results of other studies outlined in the background chapter, considers biases and constraints of the study, recommends future urban bird studies and summarizes key findings in the conclusion.

Chapter 2 Background

2.1 Characteristics of urban birds

Urban bird communities are less species rich and more homogenous than those in natural settings and are dominated by a few adaptable species which are often introduced (Jones, 1981; Biessinger and Osborne, 1982; Green, 1986; Catterall *et al.*, 1989; Clergeau *et al.*, 1989). Jokimaki *et al.* (1996) found that urban bird communities were more homogenous than communities in natural settings both throughout individual cities and between cities. Jokimaki and Kaisanlahti-Jokimaki (2003) found a 50% similarity in bird communities in suburban areas across Finland, where as there was only a 7% overlap in natural areas (Blair, 2001).

Homogenous urban bird communities most likely result from a variety of causes. First of all, urban bird species must be tolerant of high amounts of human disturbance and exotic vegetation, often with reduced structural complexity and cover compared to natural areas. Native species are also subject to displacement by exotic species. For example, Green (1983) found that the introduction of the Common Starling in Tasmania caused the decline of the Eastern Rosella and other Psittaciformes. Also, Jokimaki and Suhonen (1993) speculate that urban habitats are relatively new and few species have as of yet successfully adapted to them. Indeed, Muyenyembe *et al.* (1989) found that bird species diversity increased with suburb age in relation to increasing vegetation cover, implying that over time more species are able to colonize and adapt to urban areas.

The species which have adapted to urban areas are composed of a mixture of local and introduced species. Sewell and Catterall (1998) identified four types of urban bird species as: (1) species which were present prior to modification and use only remnant habitat patches following urbanization, (2) species present prior to modification which have adapted to urbanization, (3) species introduced to the area by humans, and (4) species from surrounding areas that colonize the urban area because they are pre-adapted to exploit it. In summary, urban bird communities are homogenous and typically composed of introduced and local species adapted to urban conditions.

2.2 Urban gradient studies

A variety of urban gradient studies have been conducted over the years, comparing city centres, business districts, industrial areas, residential areas, urban parks, agricultural areas, and remnant native habitats in a range of cities and towns around the world. While results varied somewhat based on the design of the study and location, some general trends emerged from the studies.

Many of the studies found that species richness decreased with increasing urbanization (Beissinger and Osborne, 1982; Jokimaki and Suhonen, 1993; Clergeau *et al.*, 1998; Simon et al., 2006). Likewise, the prevalence of introduced species increased with urbanization (Beissinger and Osborne, 1982; Blair, 1996; Clergeau *et al.*, 1998; Germaine *et al.*, 1998). In some studies, abundance was higher in urban than in native areas (Beissinger and Osborne, 1982). Others found that species richness was greatest at intermediate levels of human disturbance such as in agricultural areas (Jokimaki and Suhonen, 1993), golf courses and recreational areas (Blair, 1996).

Local urban habitat factors such as urban gardens (Daniels, 2005) appeared to be more important in determining urban bird communities than landscape level factors such as distance to native vegetation (Catarall *et al.*, 1989), latitude (Jokimaki and Suhonen, 1993) and climate (Clergeau *et al.*, 1998). However, Bolger *et al.*, 1997 found that edge/fragmentation sensitive species abundance varied strongly with location in the landscape.

Species level response to urbanization varied from urban specialist species, to ubiquitous species found in urban and natural areas, to urban sensitive species which disappeared as urbanization increased (Catterall *et al.*, 1989; Blair, 1996; Wood, 1996; Germaine *et al.*, 1998; Simon *et al.*, 2006). This variation in response was largely correlated with dietary habit and level of mobility. Nectarivores and insectivores decreased in prevalence as urbanization increased (White *et al.*, 2005) while omnivores were favoured (White *et al.*, 2005 and Simon *et al.*, 2006). Also, sedentary species were favoured in urban areas over more mobile ones (Jokimaki *et al.*, 1996).

2.3 Urban and urban fringe parklands

2.3.1 Native vegetation remnants

Many studies have found that native bird species richness is positively correlated with native vegetation remnant patch size (Ambuel and Temple, 1983; Freemark and Merriam, 1986; Bellamy *et al.*, 1996; Crooks *et al.*, 2001; Major *et al.*, 2001; LeFort, 2002; Lindenmayer *et al.*, 2002). There are three main theories to explain this correlation. The first is the theory of island biogeography, whereby isolated native "habitat islands" follow many of the same laws of colonization and extinction of actual islands, including that increasing size is directly related to increasing number of species colonizations (MacArthur and Wilson, 1967). The second is the nested subset theory, which predicts that in a species-area relationship only large habitat patches can contain all the local species, particularly the rare ones (Patterson, 1987). The third suggests that only large habitat patches are sufficiently buffered from edge effects to contain high quality interior habitat (Fischer and Lindenmayer, 2002).

In direct contrast to large habitat patches, studies have found that small patches often cannot sustain viable populations and are prone to local extinctions (MacNalley and Bennet, 1997; Crooks *et al.*, 2001). In this respect, small habitat patches tend to decrease in species richness over time (Crooks *et al.*, 2001). Small population sizes, reduced gene flow, barriers to dispersal, greater susceptibility to catastrophes such as wildfires, intrusion of "open-country" organisms, changes to ecological processes, altered physical regimes including microclimate change and the reduction of total population size at the local and regional scale by elimination of habitat are all factors contributing to local extinction (MacNalley and Bennet, 1997). In addition, small fragments are more likely to have high edge to area ratios rendering them more susceptible to edge effects. These can include the invasion of edge species (Villiard *et al.*, 1999), exotic vegetation and feral animals (Crooks *et al.*, 2001).

In spite of the limitations of small habitat patches they do have some value for conservation (Schafer, 1995; Fischer and Lindenmayer, 2001). First of all, the theory of island biogeography has been criticized as simplistic as species and individuals move throughout the landscape between multiple habitat patches, as supported by the meta-population theory (Opdam, 1991) and mobility is a particularly important factor in the case of birds. Indeed, small habitat patches may act as "stepping stones" between larger patches and thus contribute to overall landscape connectivity (Fischer and Lindenmayer, 2001). In addition, if there are many small habitat patches throughout the landscape, they may provide more benefits for biodiversity conservation than singly (Fischer and Lindenmayer, 2001). Small patches can also be valuable for smaller organisms which are not area-dependent such as invertebrates and reptiles (Schafer, 1995; Fischer and Lindenmayer, 2001).

The response to fragmentation is species specific (MacNalley and Bennet, 1997) and some bird species can make use of small patches. Small patches sometimes contain resources which are absent in the surrounding landscape or in larger patches, as they are often the remnant of a desirable piece of land which has largely been cleared (Fischer and Lindenmayer, 2002). Also, while they may not sustain viable populations of all the bird species in the area, small patches are used on a daily basis by many species (Bellamy *et al.*, 1996; Fischer and Lindenmayer, 2002; Lindenmayer *et al.*, 2002). Indeed, in two landscapes studied by Fischer and Lindenmayer (2002), 91% of the species detected in one landscape were found in patches of up to 10 ha, and 75% of species they found in the other landscape were in patches of less than 1 ha. In an urban context, small remnant native vegetation patches still have higher native bird diversity than the surrounding urban landscape (Wood, 1996; LeFort, 2002). Finally in many fragmented landscapes, especially urban ones, small remnant habitat patches may be the only option for conservation.

Although important, size is not the only factor to determine the conservation value of remnant patches. Trzinski *et al.* (1999) found that habitat loss, as expressed by a reduction in native vegetation cover, was more consistently detrimental to native bird species than fragmentation. Also, many studies have found that local habitat factors within remnant patches were more important than landscape level factors such as degree of isolation from other patches (Bellamy *et al.*, 1996; Villiard *et al.*, 1999; Lindenmayer *et al.*, 2002). In this context, studies have found positive correlations between native bird species richness and vegetation cover (Villiard *et al.*, 1999). Habitat heterogeneity within habitat patches was also found to be positively correlated to species richness (Freemark and Merriam, 1986; Bellamy *et al.*, 1996). In addition, the invasion of habitat patches by more open habitat species from surrounding landscapes often had a more detrimental impact on native birds than patch size itself (Grey *et al.*, 1998; Fischer and Lindenmayer, 2001; MacDonald and Kirkpatrick, 2003). In Australia, the Noisy Miner is known to exclude small woodland birds to the extent that, in some studies it was the most important predictor of the presence or absence of small woodland birds (Grey *et al.*, 1998; MacDonald and Kirkpatrick, 2003). However, it is worth noting that habitat patches with a higher edge to area ratio were more prone to invasion by edge species such as the Noisy Miner than patches with low edge to area ratios (Bellamy *et al.*, 1996).

2.3.2 Urban parks

There are many factors influencing bird diversity, abundance and species composition in urban parks and green areas including park area, park age, park vegetation structure, percent cover and species composition, presence of water, food and nest boxes, human disturbance and adjacent landscape characteristics. Many studies found that area was the most important variable affecting species richness, finding that increasing area was positively correlated with species richness (Jokimaki, 1999; Fernandez-Juricic, 2000b; Cornelis and Hermy, 2004; Platt and Lil, 2006; Chamberlain *et al.*, 2007). Also, bird species richness increased with park age (Fernandez-Juricic, 2000b) until it stabilized in parks with trees aged 97 years or older (Luniak, 1983). Bird species richness remained high with tree cover of at least 50% (Donelly and Marzluff, 2006) and increased with percent tree cover of up to about 75%, at which point it levelled off (Luniak, 1983). Vegetation layers were also positively correlated with bird species richness and abundance (Gavereski, 1976). Luniak (1983) found that vegetation structure and percent cover were more important than plant species composition. In contrast, Chamberlain *et al.* (2007) found vegetation factors to have little influence at all on bird species richness in urban parks, perhaps because all the parks they surveyed had similar vegetation characteristics. Presence of water was positively correlated with bird species richness (Luniak, 1983; Fernandez-Juricic, 2001; Chamberlain *et al.*, 2007) as was the provision of food, especially during winter (Luniak, 1983; Morneau *et al.*, 1999; Chamberlain *et al.*, 2007b). Nest boxes played a role in attracting cavity nesting species, in particular when other habitat variables were favourable (Luniak, 1983). Human disturbance especially affected shrub and ground nesting species and was compounded when there was little vegetation cover to take refuge in (Luniak, 1983 and Jokimaki; Fernandez-Juricic, 2001). Human presence (and their associated food) caused an increase in certain species, especially ground foraging granivores and omnivores

(Luniak, 1983). Off leash dogs did not appear to affect bird species richness (Forest and Cassady St. Clair, 2006). Presence of adjacent buildings had a negative effect on bird species richness (Jokimaki, 1999; Chamberlain *et al.*, 2007) while presence of adjacent gardens and wooded streets increased species richness in urban parks (Fernandez-Juricic, 2000b; Chamberlain *et al.*, 2007). Adjacent bird communities were a bigger influence in urban park bird communities in younger, smaller parks than in older, larger ones (Frendandez-Juricic, 2000b). In general, location within the city did not influence bird communities in urban parks, but Jokimaki (1999) found that species with larger habitat requirements were not found in parks near the city centre. In summary, bird species richness, abundance and species composition in urban parks are influenced by a variety of factors, including characteristics of the park itself, degree of human presence in the park and adjacent landscape characteristics.

In spite of the many factors influencing bird species in parks, certain similarities existed in the studies. For one, just as in other urban habitats, birds in urban parks tended to be more abundant and less species rich than in native vegetation remnants (Donelly and Marzluff, 2006). Also similarly to other urban habitats, urban parks favoured granivores and omnivores which were ground foragers and nested in trees and disadvantaged shrub and ground nesting birds which had specialist dietary requirements (Luniak, 1983; Fernandez-Juricic, 2000b). Finally, urban parks and green areas often have the highest bird diversity of the urban habitat types (Fernandez-Juricic and Jokimaki, 2001) and therefore may be valuable for conservation in an urban context.

2.4 Habitat quality

2.4.1 Vegetation

Many studies have found a positive correlation between native birds and native plants (Catterall *et al.*, 1989; Green *et al.*, 1989; Daniels and Kirkpatrick, 2007). Mills *et al.* (1989) found a positive correlation between native birds and native vegetation volume. Green *et al.* (1989) found that native birds foraged on native plants more frequently than exotic birds did. Daniels (2005) found that native birds were most abundant in native gardens. In the Australian garden context, Banksias and Grevilleas were found to be particularly appealing to particular types of native birds (Daniels, 2005; French *et al.*, 2005). On the whole, Muyenyembe *et al.* (1989) found that sites with native vegetation were more species rich than sites with exotic vegetation.

By contrast, exotic birds were found to favour exotic plants (Green, 1986). Mills *et al.* (1989) found a positive correlation between exotic vegetation volume and exotic birds and Green (1986) found that exotic plant species richness was positively correlated with exotic bird species richness. Not only was there a positive correlation between exotic birds and exotic plants, there was also a negative correlation between native plants and exotic birds (Green, 1986).

Besides plant species composition, vegetation cover had an important influence on birds. Studies found a positive correlation between bird species richness and percent cover of vegetation in both urban (Beissinger and Osborne, 1982; Munyenyembe *et al.*, 1989; Fernandez-Juricic, 2000a) and natural settings (Villiard *et al.*, 1999). In an urban setting, Clergeau *et al.* (1998) found that native bird species were most common in well vegetated areas. By contrast, Hennings and Edge (2003) found that exotic species abundance decreased with increasing canopy cover.

In addition to vegetation species composition and cover, vegetation complexity was another important influence on birds. Many studies have found a positive correlation between bird species richness and abundance and increasing vegetation complexity (Gavereski, 1976; Beissinger and Osborne, 1982; Luniak, 1983). In support of this finding, Sewell and Catterall (1998) found that many bird species are sensitive to understorey loss.

2.4.2 Invertebrates

Invertebrate response to urbanization and fragmentation is similar to that of birds, as supported by studies comparing the response of both at the same location (Blair, 1999; Bolger *et al.*, 2000). For example, invertebrate species richness corresponds to fragment size (Burke and Nol, 1998; Miyashita *et al.*, 1998; Bolger *et al.*, 2000) just as for birds. Likewise, many studies found that species richness and abundance declined in fragmented (Wolf and Gibbs, 2004) and urbanized (Rango, 2005) environments. However, MacIntyre *et al.* (2001) and Alaruikka *et al.* (2002) found there was no difference in species richness and abundance of arthropods between rural and urban sites, but there was a difference in species composition. Also, just as with birds, there was a higher prevalence of introduced invertebrates in urbanized landscapes (Blair, 1997) than in more natural ones, in some cases causing the displacement of native arthropods. For example, the introduced Argentine ant, now found worldwide in Mediterranean climates, has been associated with declines in a wide variety of arthropods (Bolger *et al.*, 2000). Other trends include decreasing species richness with decreased fragment age (Bolger *et al.*, 2000) and decreasing arthropod body size with decreasing fragment size (Miyashita *et al.*, 1998) and increasing urbanization (Alaruikka *et al.*, 2002).

As was the case for birds, invertebrate response to urbanization and fragmentation varied according to dietary habit, taxanomical group and species. For example, in terms of dietary habit, most studies found that native predators were less abundant in more urbanised environments than in natural ones (MacIntyre *et al.*, 2001; Rango, 2005), although Bolger *et al.* (2005) found them to be more abundant in small fragments than larger ones. Omnivores were present in all habitat types (MacIntyre *et al.*, 2001). In another diurnal taxon, Blair (1997) found that butterfly abundance declined with urbanization. Also, native ants are particularly sensitive to urbanization (Rango, 2005), perhaps due to displacement by the introduced Argentine ant.

Another trend which was the same for invertebrates as for birds was that they responded strongly to environmental variations such as vegetation and season. For example, Guillano *et al.* (2004) found a positive correlation between plant and Lepidoptera species richness and relative abundance in urban parks in New York. Also, studies in Australia have shown that invertebrate species richness is higher on native than exotic trees (Green, 1986; Bhullar and Majer, 2000). Additionally, many studies found a large seasonal variation in arthropod species richness and abundance (Bolger *et al.*, 2000; Rango, 2005).

Invertebrate responses to urbanization and fragmentation have important implications for birds as they are an important food resource for many bird species. For example, Green (1986) found that native birds foraged more often on native trees as a learned response to the greater invertebrate abundance on the native trees. The large number of introduced plants in urban areas may therefore be linked to declines in both invertebrates and birds. In fact, many urban bird studies have noted a decline of insectivorous birds in particular in urban areas (White *et al.*, 2005; Lim and Sodhi, 2004). In a more natural setting, Burke (1998) found that Ovenbird density increased with fragment size in relation to increasing invertebrate biomass, implying a direct relationship between bird density and invertebrate biomass.

2.4.3 Human disturbance

Studies have shown built environments have a negative influence on bird species richness (White *et al.*, 2005). Many urban gradient studies have found that the most built environments such as city centres to be the least species rich (Beissinger and Osborne, 1982, Jokimaki and Suhonen, 1993, Clergeau *et al.*, 1998). Germaine *et al.* (1998) found that native bird species richness declined with increasing housing density and Chamberlain *et al.* (2007) found that the presence of buildings adjacent to urban parks had a negative influence on species richness in the parks.

However, while a built environment appears to have a purely negative impact on native species (Lim and Sodhi, 2004), it has a mixed impact on exotic species. Lim and Sodhi (2004) found that exotics were most favoured by an intermediate level of built environment and White *et al.* (2005) found that anthropogenic features including buildings and paved areas favoured introduced species, especially House Sparrows and Rock Doves. Green (1986) and Green *et al.* (1989) found that exotic species perched on built structures more often than native species.

Besides built environments, pedestrian traffic can have negative impacts on bird populations (Luniak, 1983; Gutzwiller *et al.*, 1998; Fern andez-Juricic, 2000a). The presence of humans, referred to by Gutzwiller (1998) as human intrusion, can be detrimental to birds by causing displacement, preventing access to resources and reducing reproduction and survival (Gutzwiller *et al.*, 1998). Researchers have observed that bird response to the presence of humans is similar to their response to predators (Gill *et al.*, 1996). Nevertheless, results on the impact of human presence on birds are mixed. Fernandez-Juricic (2000a) found that pedestrian traffic exerted a negative influence on bird species richness, guild density and probability of the presence of individual species. Riffell *et al.* (1998) found that some common species experienced a decline in species richness and abundance in response to repeated intrusions by humans during the breeding season over five years, but that the effects were not cumulative. Finally, Platt and Lil (2006) found that bird species distribution was not correlated to pedestrian traffic.

The mixed results of human intrusion studies may reflect the fact that avian response to human intrusion varies by species and context (Gill *et al.*, 1996 and Gutzwiller *et al.*, 1998). For example, Gutzwiller *et al.* (1998) found that conspicuous species and species which were active closer to the ground were more sensitive to human intrusion than less conspicuous species and species active further from the ground (as measured by flushing distance and detectability period before flushing). Likewise, Cooke (1980) found that larger species were more sensitive to human approach than smaller ones (again measured by flushing distance). In terms of context, birds were less sensitive to human approach in the presence of conspecifics (Gutwiller *et al.*, 1998), when vegetation cover was higher (Luniak, 1983 and Gutwiller *et al.*, 1998) and in suburban as opposed to rural settings (Cooke, 1980). Even the colour of the person's clothing had an affect on flushing distance for some species (Gutzwiller *et al.*, 1997). Time of day, season and the presence of heterospecifics did not appear to affect avian sensitivity to human presence (Gutzwiller, 1998).

Vehicle traffic can also have a negative impact on birds. Reijnen *et al.* (1995) found that 26 (60%) of the 43 species they studied showed a reduction in density up to 1500m from roads with up to 10,000 cars a day and up to 2800m from roads with up to 60,000 cars a day. This was found to be primarily due to the noise level of the traffic, as varying noise level did influence bird densities whereas the visibility of the cars did not. Vehicle mortality and pollution were also considered unimportant factors in explaining the reductions in density (Reijinen *et al.*, 1995).

Chapter 3 Methods

3.1 Study Location and Sites

This urban bird study takes place in Hobart, the capital city of the Australian state of Tasmania. It was first settled by Europeans in 1803 as a penal colony and is currently the largest city in Tasmania (Tourism Tasmania, 2007). Nevertheless, it is a mid-sized city with a population of 199,878 and an area of 125 square kilometers (Australian Bureau of Statistics, 2003). Hobart is a good representative of an urban area as the majority of the world's cities have populations of under one million (Satterthwaite, 2000) and its many urban and native remnant parklands suit the aims of this study. It is set at a latitude of 42.89 ° S and a longitude of 147.33 ° E. Hobart has an annual average precipitation of 600mm and has mean maximum and minimum temperatures of 21.6° C and 12.0 ° C and 11.6 ° C and 4.6 ° C for summer and winter, respectively (Bureau of Meterology, 2007a and Bureau of Meterology, 2007b).

Five sites were selected in and around the Hobart CBD to represent a range across the urban gradient from highly developed to relatively free of human disturbance. They were chosen in close proximity to one another to minimize the influence of location in the landscape on the results of the study. They were also chosen to be of comparable size to one another so the results reflect habitat quality, which is the focus of this study, rather than size variation amongst the sites. The sites are, from most to least developed, Hobart, Sandy Bay, the Queen's Domain, Bicentennial Park and Knocklofty Reserve (Figure 3.1). Note that the more developed sites are closer to the foreshore while the less developed wooded sites are mostly on slopes further inland. The following is a more detailed description of each of the sites individually.

(i) Hobart: The city centre and commercial district of Hobart, it is largely a built environment with government and private offices, restaurants and retail shops lined streets with high vehicle and pedestrian traffic and noise levels (Photographs 3.1, 3.2 and 3.4). It is approximately 51m in altitude (BOM, 2007a). It is very sparsely vegetated with exotic street trees and potted flowers. Fauna is scarce, and is mostly introduced. It is roughly 135 ha in size. Eight urban streets and six urban parks were included in the study in Hobart.

(ii) Sandy Bay: Sandy Bay is largely a residential area with moderate vehicle and pedestrian traffic and noise (Photographs 3.3, 3.5 and 3.6). It has an elevation similar to Hobart. It has more vegetation than the Hobart city centre due for the most part to plants in people's gardens in addition to street plantings. Vegetation varies considerably across gardens. Daniels (2005) recognized 12 garden types in Hobart suburbs including low and no input exotic gardens, low and high rainfall native gardens, complex flower and flower and vegetable gardens, among others. Pet dogs and cats, feral cats and rats, brush-tailed possums, birds and a few introduced invertebrates are the most commonly occurring fauna in Sandy Bay. It is roughly 140 ha in area. Nine urban streets and six urban parks were included in the study in Sandy Bay.

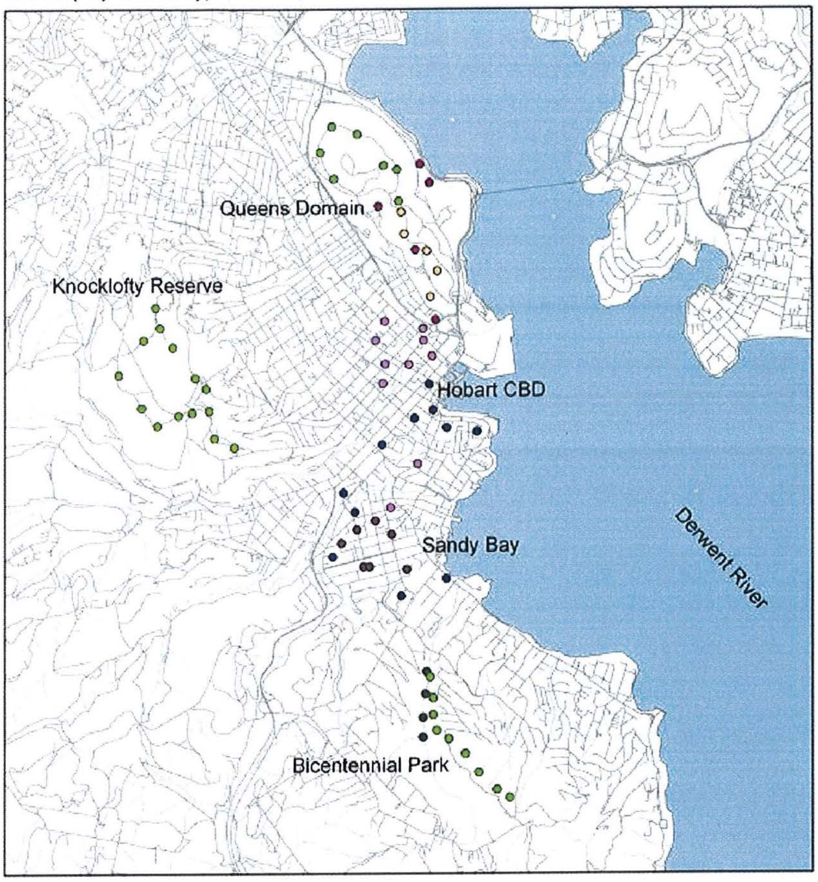
(iii) Queen's Domain: The site of the Governor's house since 1821, the Queen's Domain (with the exception of the Governor's house and Royal Botanical Gardens which is still crown land) was given to the public to be managed by the Hobart City Council in 1917 (Photographs 3.7-3.11). It is used recreationally for bushwalking, jogging, dog walking, picnicking and for sporting and other special events. The Queen's Domain is roughly 170 ha in area and ranges in elevation from sea level to 90 metres. Set on Jurassic dolerite bed rock with black clay soils (de Gryse, 1996), it has three main habitat types. The first habitat type includes the sporting grounds and Royal Botanical Gardens which are composed of exotic lawns and a mixture of various other exotic and native vegetation. The second is open grassy woodland dominated by *Eucalyptus viminalis* in the tree layer and *Themeda triandra* on the ground (Kirkpatrick, 1995 and Kirkpatrick, 2004). The third is a grassy woodland dominated by *Allocasuarina verticillata* and *Eucalyptus viminalis* with a mixed shrub under-storey including *Acacia mearnsii* and *Bursaria spinosa* with *Themeda triandra* still dominating the ground level (Kirkpatrick, 1995 and Kirkpatrick, 2004). The central location of the Queen's domain and relatively high traffic levels are responsible for a host of introduced plants present in the Domain, including *Plantago lanceolata* and *Urospermum* sp. to name two of the most common ones. These three habitat types are sufficient for a bird study of this nature, but it is worth noting that Kirkpatrick (2004) recognizes six plant community types to be present at the Queen's Domain. The Queen's Domain is less rich in fauna than the other reserves in this study, but the brush-tailed possum, four species of lizards and skinks, birds and a wide variety of invertebrates are known to occur there.

(iv) Bicentennial Park: Sir Lambert Dobson donated 4.05 ha (Lambert Park) to the Queensborough Town Board in 1896 which amalgamated with the Hobart City Council in 1913 (Photographs 3.12-3.14). The 60.71 ha Skyline Reserve was acquired by the Hobart City Council in 1950 and subsequent acquisitions have made it the 130 ha reserve it is today. Its name was changed to Bicentennial Park in 2000. It has low to moderate pedestrian traffic consisting of bushwalkers, dog walkers, joggers and researchers. It ranges in elevation from approximately 70 to 330m and is largely on a slope. It is set on Jurassic dolerite bedrock with soils varying from shallow stony grey-brown or yellowish brown sandy clay loams on upper slopes to deeper stony brown clay loams on middle and lower slopes (Sharples, 1998). Two habitat types are recognized for the purposes of this study- wet sclerophyll forest and dry sclerophyll woodland. The former is much more densely vegetated than the latter and consists of a *Eucalyptus globulus* over-storey, a dense shrubby under-storey dominated by *Beyeria viscosa* and *Bedfordia salicinia* and a ground storey which includes ferns such as *Microsorum diversiflorum* and grasses. The dry sclerophyll woodland has over-stories dominated by a range of species including *Eucalyptus globulus, Eucalyptus viminalis, Eucalyptus ovata, Eucalyptus pulchella* and *Allocasuarina verticillata.* Under-storey dominants include *Bursaria spinosa, Dodonaea viscosa* and *Banksia marginata* with *Lomandra longifolia* and *Themeda triandra* dominating the ground layer (Hickie, 1998). The narrow shape of the reserve bordered by a residential area lends itself easy invasion by exotic species. *Cotoneaster* spp., *Crataegus monogynus* and *Rubus fruticosus* are common weeds in the reserve (Hickie, 1998). In addition to these habitats, seven smaller scale plant community types are known to occur in the reserve. Two species of frog, eight species of skink and lizards including the blotched blue tongue lizard, all three Tasmanian land snakes, ten species of mammals including introduced rabbits and rats, and countless invertebrate species occur in the reserve (Hird, 1994).

(v) Knocklofty Reserve: From European settlement until it was compulsorily acquired by the Hobart City Council in 1942, Knocklofty was privately owned and used for timber cutting, livestock grazing and stone quarrying (Brown, 1983) (Photographs 3.15 and 3.16). Since the Hobart City Council acquired it, a few small additions have been made to the reserve which is currently 144 ha in size. It is currently used primarily by dog walkers, bushwalkers and joggers. It ranges from 120 to 372 meters in elevation with much of it set on slopes between 6-20 degrees (Brown, 1983). The majority of the reserve is set on Jurassic dolerite except for the east facing slope which is on Triassic Sandstone. The majority of the reserve has black clay loam soil with a yellow-grey subsoil (on dolerite) and a small part of it was grey-brown loamy sand with a bleached sub-surface (on sandstone) (Brown, 1983). The Reserve is dominated by dry sclerophyll and grassy forest with 14 vegetation types described. *Eucalyptus globulus, Eucalyptus pulchella* and *Eucalyptus viminalis* are the most widespread over-storey species while *Bursaria spinosa, Banksia marginata* and various species of Acacia are common in the under-storey. *Lomandra longifolia* and grasses such as *Poa rodwayi* and *Themeda triandra* dominate the ground layer. *Ulex europaeus, Rubus fruticosus* and *Chrysanthemoides monilifera* are among the common introduced species (Brown, 1983). Brush-tailed possums, potoroos, brown bandicoots, quolls, rabbits and all three species of Tasmanian land snakes are some of the commonly occurring fauna in the reserve, as well as the birds described in this thesis and countless invertebrates (Brown, 1983).

On the site map on the following page (Figure 3.1), the five sites are labelled and count points are marked by dots which are colour-coded by habitat type.

Site Map by Habitat Type, Hobart, Tasmania



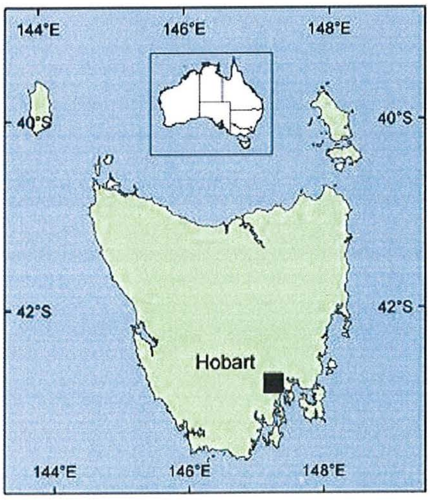
Base data from theLIST, © State of Tasmania

N

0 2 Km

Projection: UTM, Zone 55
Datum: GDA 94

Tasmania, Australia

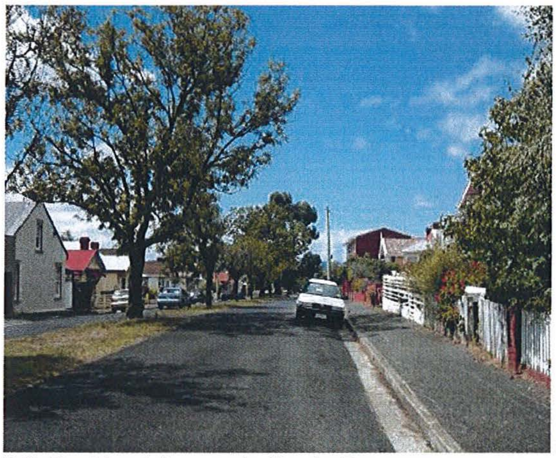


Habitat Type

- Commercial
- Exotic
- Grassland
- Residential
- Urban Park
- Wet Forest
- Dry Woodland
- Roads
- Drainage
- Sea

Urban Sites: Hobart and Sandy Bay[1]

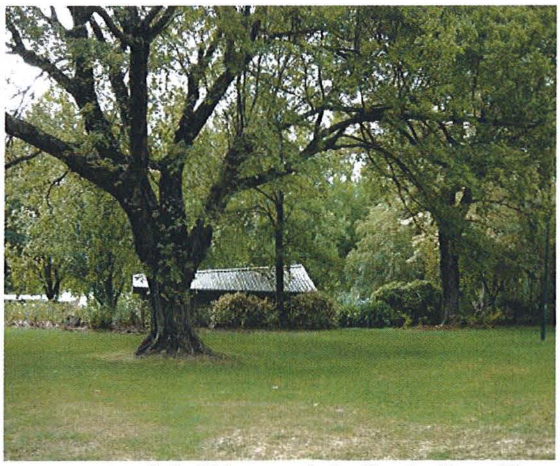
3.1 and 3.2: commercial streets in Hobart city centre.



3.3: Residential street in Sandy Bay.

3.4: Urban park in Hobart: Salamanca Square.

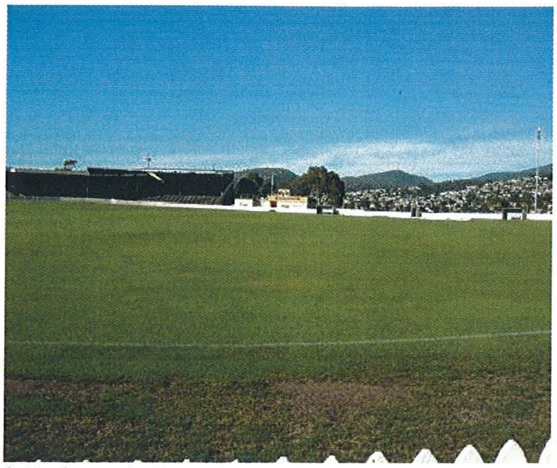
3.5: Urban park in Sandy Bay: university campus.



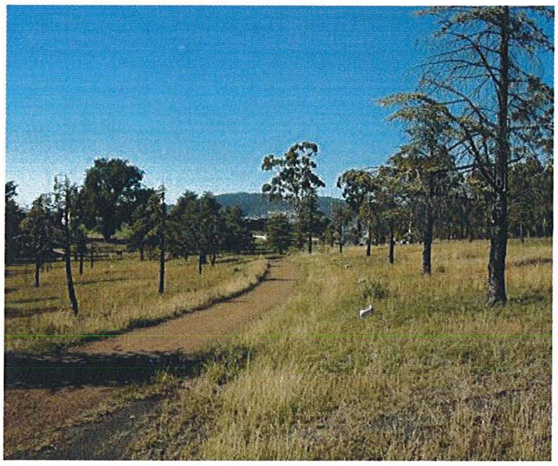
3.6: Urban park in Sandy Bay: Fitzroy Gardens.

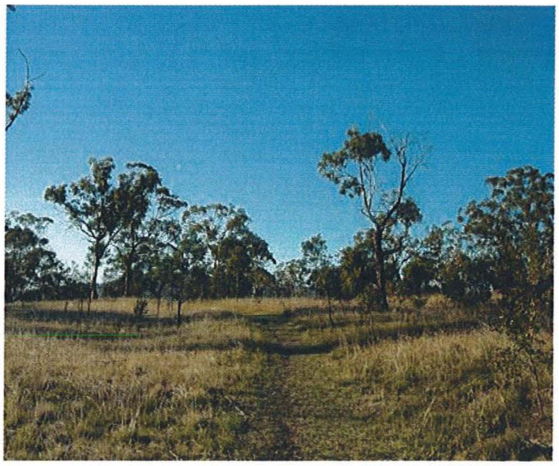
[1] All site photographs were taken in February, 2007.

Exotic and Woodland Sites: The Queen's Domain



3.7: Queen's Domain exotic site: cricket grounds.
3.8: Queen's Domain exotic site: Botanical Gardens.

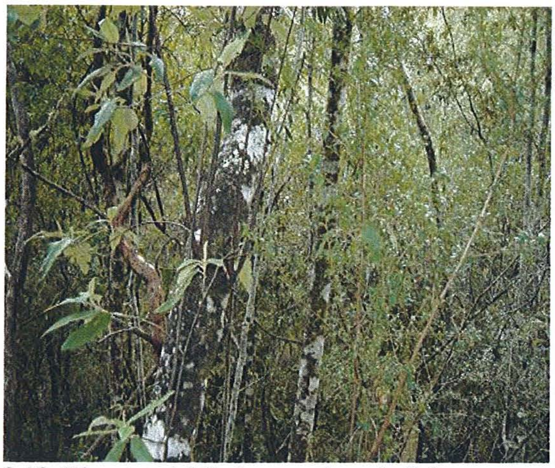




3.9 and 3.10: Queen's Domain grassland.

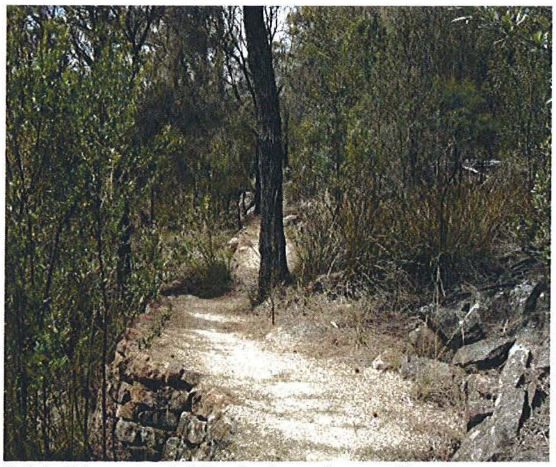
3.11: Queen's Domain she-oak woodland.

Woodland Sites: Bicentennial Park and Knocklofty Reserve



3.12: Bicentennial Park wet sclerophyll forest.

3.13: Bicentennial Park dry sclerophyll woodland.



3.14: Bicentennial Park she oak woodland.

3.15: Knocklofty Reserve Eucalypt woodland.

3.16: Knocklofty Reserve dry sclerophyll woodland.

3.2 Bird Surveys

3.2.1 Survey technique

The goal of a good surveying technique is to maximize the quality of the data obtained, minimize the sources of bias and obtain data suited to the aims of the study. Sources of bias are many including observer disturbance and competency at identifying birds, technique employed, effort and speed of the survey, variability among species in detectability, variability in bird density and activity level, season, time of day, weather (Bibby *et al.*, 2000) and subjective choice of sampling sites (Unwin, 2007, pers. com.). Good survey design can help to minimize these biases.

There are four primary techniques for assessing bird diversity and abundance including capture-mark and recapture, area search, line transect and point count methods (Bibby *et al.*, 2000). The capture-mark and recapture method is just as its name implies, the area search involved searching a fixed area for a fixed time period and recording all birds seen or heard, the line transect involves walking slowly along a transect of a fixed length and recording all birds seen or heard within a given distance of the transect and the point count method involves standing at a number of fixed points for a fixed amount of time and recording all birds seen or heard within a pre-determined distance of the point. There is no perfect technique and each of them have their strengths and shortcomings and vary in their suitability depending on the aims and conditions of the study.

The capture-mark and recapture was not a feasible option for this study due to time and budget limitations. The area search method was discarded because it is inefficient for surveying large areas. Therefore the line transect method and the point count method were those considered for this study. Line transects are most efficient per unit of effort (Bibby *et al.*, 2000) but are of limited utility in dense and/or variable habitats (Bibby *et al.*, 2000). Point counts are suitable for large areas and in woody habitats which are variable (Bibby *et al.*, 2000), but are inaccurate in determining bird densities (DeSante, 1986; Bolinger *et al.*, 1988) and tend to overlook cryptic species (Loyn and Hewish, 1989).

As habitat quality is an important factor in this study, the point count was chosen. Using the "rolling" point count method (Loyn and Hewish, 1989) (where counts are conducted at multiple points at regular intervals throughout a given site), more ground can be covered within sites, thus accounting for habitat variability better than a fixed line transect can. The point count method also allows for habitat data to be gathered at the count points themselves for direct comparison with bird data gathered there (Bibby *et al.*, 2000). Also, Pomeroy (1997) found that the point count method detected species at a faster rate than the transect method and was suitable for most habitat types. The point count method also minimizes observer disturbance to birds as compared to the line transect and area search methods, as the observer remains stationary. As this study did not seek to measure bird density, the limitation of this method for doing so was not considered a problem. The tendency to over-look cryptic species was compensated for by "searching" within 50m of the count point in dense habitats where detection was poor or in when a bird song was not initially recognized. However, this technique was only used in the densest habitats when detection was low in order to maintain the benefits of remaining stationary in most cases. Also, species detected while travelling between count points which were not detected at any count point were recorded for total species richness of a site, but not for any other part of the analysis.

For this study, 5 minute counts were conducted at each point. One count point was used for every 10 ha of a site so that Hobart had 14 count points, Sandy Bay had 15, the Queen's Domain had 17, Bicentennial Park had 13 and Knocklofty Reserve had 15 for a total of 74 count points, each surveyed a total of six times. Of these 74 count points, 10 were in a commercial "habitat", 7 were in a residential, 17 were in urban park and 40 were in various types of woodland habitats in the bushland reserves described in the previous section. All mention of the words "count point" refer to these points.

3.2.2 Season, Time and Weather

Six surveys were conducted at each of the five sites over summer and autumn, 2007 to account for seasonal variation in bird species composition. Day length was recorded on each survey day. Survey dates are shown in Table 3.1, but will henceforth be referred to sequentially by site (e.g. Hobart, survey day 1, etc.).

HOBART	SANDY BAY	QUEEN'S DOMAIN	BICENTENNIAL PARK	KNOCKLOFTY RESERVE
08/02/2007	11/02/2007	13/02/2007	10/02/2007	09/02/2007
19/02/2007	23/02/2007	21/02/2007	22/02/2007	20/02/2007
26/02/2007	05/03/2007	02/03/2007	01/03/3007	27/02/2007
13/03/2007	12/03/2007	09/03/2007	07/03/2007	08/03/2007
28/03/2007	29/03/2007	25/03/2007	26/03/2007	27/03/2007
02/04/2007	10/04/2007	01/04/2007	04/04/2007	03/04/2007

Table 3.1: Survey dates for the five study sites. Day length varied from 14 hours and 5 minutes on the 18th of February to 11 hours and 10 minutes on the 10th of April, decreasing approximately two minutes per day over the nine week study period.

Surveys were conducted between sunrise and 11:30am as studies have shown that more birds are detected earlier in the day. Slater (1994) found that bird detection peaked within the first hour of sunrise and declined by the hour thereafter, while Ratkowsky (1978) found that detection rates were similar until 11:30am at which point they declined. Both had higher detection rates before 11:30am, which is the basis for the design of this study.

In addition to time of day, weather can affect the number of birds detected. Ratkowsky and Ratkowsky (1979) and Slater (1994) found that wind correlated negatively with bird numbers seen. Slater (1994) also found the low temperature correlated negatively with bird numbers. Light rain did not appear to affect bird numbers (Ratkowsky and Ratkowsky, 1979). Consequently, surveys in this study were conducted in light rain and fine conditions but not in wind or heavy rain. Weather conditions including temperature, percent cloud cover and whether it was fine or raining were recorded on each survey day.

3.2.3 Bird Data Collected

Bird data was based on terrestrial, diurnal bird species and excluded all aquatic and nocturnal species such as gulls and owls. The Masked Lapwing was an exception to this rule because it commonly utilized terrestrial urban environments during daylight hours and thus was considered important for inclusion in an urban bird study of this nature.

Bird data collected included species, number, location, behaviour, plumage and whether it was identified by sight or by call. Birds were included within an estimated 50m radius of the count point. Birds were recorded by the correct species except in the case of the Tasmanian Thornbill, which were called Brown Thornbills unless they were very clearly the former, because these two species are difficult to distinguish from one another. Location information included the approximate distance and direction the bird was from the count point, the height it was seen at (ground: 0-2m, shrub: 2-4m, tree: 4-8m and air: 8-30m) and the object it was perched on including native/exotic tree/shrub, ground or built object. Both habitat utilising and non-habitat utilising behaviours were recorded. The former was defined as behaviours involving direct physical contact with an object in the environment, such as perching and the latter as behaviours not involving physical contact with an object in the environment such as flying. Birds that were heard and not seen were recorded to be singing. Plumage indicated whether the bird was adult or juvenile and in some species distinguished between sexes (see Appendix I and II for an example of a data sheet and guide to species codes).

3.3 Environmental Data

3.3.1 Vegetation

To assess vegetation species composition, samples of the most common plants within 50m in all directions of all count points were identified by botanical expert Prof. J.B. Kirkpatrick and at the Tasmanian herbarium. Plants in people's gardens which could not be easily accessed were necessarily excluded. Plants were identified at least to genus and to species whenever possible, except for a negligible number which could not be identified even generically. These few were classified as "unknown exotic/native grass/shrub/tree".

Vegetation structure was assessed by estimating height and percent cover of the vegetation. Percent cover of vegetation was estimated in each of four height classes which were as follows: ground layer= 0-0.5m, shrub layer= 0.5-2m, middle storey= 2-8m and over-storey= 8-30m. There were six percent cover categories including: 0= 0% cover, 1= 0-10% cover, 2= 10-25% cover, 3= 25-50% cover, 4= 50-75% cover and 5= 75-100% cover. Percent cover of bare soil and dead leaf/wood litter were also estimated.

3.3.2 Invertebrates

Three undergraduate research assistants sampled plants at two locations at each of the five sites for invertebrates. All mention of the word "location" in reference to the study sites refers to these invertebrate sampling locations. Eight plants were sampled at each location to ensure adequate replication. The two sampling locations at each site were selected to be at opposite sides of the site and/or in different habitat types to encompass diversity within the site. At Knocklofty Reserve and Bicentennial Park this was near the two opposite entrances to the reserves and at the Queen's Domain it was in the grassland and woodland habitat types. All urban sampling locations were urban parks as it was not feasible to sample invertebrates on city streets because the majority of the plants were on private property. Each sampling locations was sampled only once during the same study period in which the bird surveys took place. Sampling sites were denoted as KL (Knocklofty Reserve), BP (Bicentennial Park), QD (Queen's Domain), SB (Sandy Bay) and HO (Hobart), with a 1 or 2 to distinguish sampling locations within sites, and letters A-H to denote the eight plants sampled at each location.

Sampling was accomplished by spraying the plants (trees and shrubs) with the insecticide Pyrethrin, and laying a tarp underneath the plant to catch falling invertebrates. Alternatively, the plant was shaken to dislodge the invertebrates. These methods were selected over removing bark to standardize methods between bark deciduous (Eucalyptus family) and non bark deciduous (mainly exotic) plants. Fallen invertebrates were put in 70% ethanol solution with a label stating the date, location and plant species the invertebrates were found on. GPS coordinates were taken of the sample locations. In the lab, the invertebrates were identified at least to family and to genus and species whenever possible.

3.3.3 Human Disturbance

Degree of human disturbance was measured by an estimation of degree of vehicle and pedestrian traffic and the percent cover of built structures. Vehicle and pedestrian traffic levels were recorded as 1, low (less than five vehicles and/or pedestrians per minute), 2, moderate (5-10 vehicles and/or pedestrians per minute) or 3, high (greater than 10 vehicles and/or pedestrians per minute) at each count point by visual estimation at the time of the bird surveys. Human noise level was estimated as high (3), moderate (2) or low (1). Percent cover of built structures was estimated at each count point by the same six categories used for vegetation cover.

3.4 Statistical analysis

3.4.1 Question 1: Bird species diversity, abundance and composition

Species richness was used to compare bird diversity among sites using species accumulation curves and an excel bar chart. Species accumulation curves are useful for assessing whether the majority of species present at the site have been observed (Bennett and Ford, 1997; Moverly, 1997). A species accumulation curve comparing all five sites was used for this purpose. However, the short term nature of this study makes the detection of all species present at the sites impossible, so this species accumulation curve is meant more for an overall comparison of species richness between sites rather than total species richness at any one site. The bar chart compares total species richness, number of introduced, native and endemic species between sites.

Excel bar charts were used to show the average number of native and introduced individuals at each site (average abundance) and broad habitat type. Sites were classified as previously stated and the five broad habitats were as follows: Knocklofty woodland and Bicentennial woodland were the same as Knocklofty Reserve and Bicentennial Park, the Domain woodland was the native vegetation parts of the Queen's Domain, urban parks included parks in Hobart, Sandy Bay and the exotic vegetation parts of the Queen's Domain, and urban streets included streets surveyed in Hobart and Sandy Bay. The first three were native vegetation woodland habitat types (which included multiple vegetation types), the urban parks were primarily unpaved exotic vegetation habitat types and urban streets were primarily paved habitat types with varied vegetation cover from front gardens and city landscaping. All future mention of the word "site" refers to the five sites described on pages 17-20 which are based on location in the landscape and all future mention of the word "habitat" (unless it is specified that the smaller scale habitats are indicated, see p. 32) refers to the five broad habitats based on habitat quality, which may overlap two or more sites (as described previously).

Relative species composition was assessed by species classification and ordination. Species were classified into five categories based on how abundant and widespread they were and how frequently they occurred within each of the broad habitat types. Categories were as follows:

Woodland specialists: species which occurred only at woodland habitats, or much more abundantly, frequently and were more widespread at woodland sites than at urban sites.

Woodland generalists: species which were significantly more abundant and widespread and occurred more frequently in woodland habitats than urban ones, but also occurred in urban habitats.

Generalists: Species which were almost equally abundant, widespread and frequently occurring in woodland and urban habitats.

Urban generalists: Species which were significantly more abundant, widespread and occurred more frequently at urban habitats than woodland habitats, but also occurred at woodland habitats.

Urban specialists: species which occurred only at urban habitats, or much more abundantly, frequently and were more widespread at urban sites than at urban habitats.

Similar habitat specialization classification systems have been adopted by Wood (1996) to show habitat-species relationships. Abundance was measured as the average abundance of a species per count point at each broad habitat type, degree of widespreadness by the proportion of count points the species was found at in each broad habitat type, and frequency of occurrence by the average percentage frequency of occurrence of a species at count points in each broad habitat type. Categorical definitions on the basis of these three criteria are below (Table 3.2).

Species Type	**Abundance**	**Widespreadness**	**Frequency of Occurence**
Woodland Specialist	0-0.15 U	0-0.2 U	0-3.0% U
Woodland Generalist	0.16-0.25 U	0.21-0.5 U	3.1-15.0% U
Generalist	U<0.25 diff. from W	Not defined	U<5% diff. from W
Urban Generalist	0.16-0.25 W	0.21-0.5 W	3.1-15.0% W
Urban Specialist	0-0.15 W	0-0.2 W	0-3.0% W

Table 3.2: Ranges of average abundance (abundance), proportion of count points species is found at (widespreadness) and average percentage frequency of occurrence (frequency of occurrence) which define the five species types in terms of habitat preferences. U= ranges of abundance, widespreadness and frequency of occurrence relate to species occurrence in urban habitats, W= they relate to species occurrence in woodland habitats.

Two ordinations were used to explore habitat-habitat, habitat-species and species-species relationships. The first was used to visualize any relationships between species compositions at the five broad habitat types. The second was used to show the relationship of species compositions between habitats at a finer scale, using 11 habitat types. The 11 habitats included Hobart and Sandy Bay commercial streets (1), Sandy Bay residential streets (2), Hobart urban parks (3), Sandy Bay urban parks (4), Queen's Domain exotic count points (5), Queen's Domain grassland count points (6), Queen's Domain woodland count points (7), Bicentennial Park wet woodland count points (8), Bicentennial Park woodland count points (9), Knocklofty woodland east slope count points (10) and Knocklofty woodland west slope count points (11). Both ordinations were done using non-metric multidimensional scaling (NMS) in the computer program PC-Ord. NMS has been shown to produce the least distortions in data with large numbers of zeros (Minchin, 1989).

3.4.2 Question 2: Assessing the value of parks

One-tailed t-tests were used to compare the difference in mean native species richness between urban parks and surrounding habitats and between all urban habitats and all native woodland habitats. Comparisons included: all urban vs. all woodland count points, all urban streets vs. all urban parks (including the Queen's Domain exotic sites), Hobart urban streets vs. Hobart urban parks, Sandy Bay urban streets vs. Sandy Bay urban parks, Queen's Domain exotic vs. Queen's Domain grassland count points and Queen's Domain exotic vs. Queen's Domain woodland count points. A P-value of less than 0.05 denoted statistical significance. A bar chart with standard error bars was used to show a visual relationship between mean species richness at urban parks and adjacent streets or woodland.

3.4.3 Question 3: Assessing the influence of habitat quality

1. Vegetation:

Plant species were arranged in an Excel file by broad habitat type in order from most to least widespread across all habitat types (as measured by the mean percentage of count points each species was found at). A bar chart was used to summarize variation in total plant species richness, number of native, mainland native and introduced species among the broad habitat types. They were then ordinated by broad habitat type using the same technique used for the bird ordinations.

Correlation analysis was performed to assess the relationship between birds and plants using Minitab. Native, introduced and mainland native plant species richness were tested for correlation with bird species richness.

Birds were tested for correlation with plants as all native species and in six categories based on niche and evolutionary relationship. Group names are based on the family name or type of species which are most numerous within groups. A few of the species listed could have arguably have been placed in a different group. For example, the Superb Fairywren is similar to species in the thrush group and in the thornbill group, but it was decided to place it in the thrush group for the purpose of statistical analysis of this study. The six categories, from most to least abundant, were as follows (species are also listed from most to least abundant within groups):

Introduced group: Rock Dove, House Sparrow, European Blackbird, Common Starling, Spotted Turtle-dove, European Goldfinch, Laughing Kookaburra and European Greenfinch.

Thornbill group: Brown Thornbill, Spotted Pardalote, Silvereye, Striated Pardalote, Tasmanian Scrubwren and Tasmanian Thornbill.

Honeyeater group: Yellow-throated Honeyeater, Little Wattlebird, Yellow Wattlebird, Noisy Miner, Black-headed Honeyeater, New Holland Honeyeater, Eastern Spinebill, Strong-billed Honeyeater and Crescent Honeyeater.

Rosella group: Musk Lorikeet, Eastern Rosella, Sulphur-crested Cockatoo, Green Rosella and Yellow-tailed Black Cockatoo.

Corvid group: Forest Raven, Australian Magpie, Grey Currawong and Grey Butcherbird.

Thrush group: Grey Fantail, Scarlet Robin, Grey Shrike-thrush, Dusky Wood-swallow, Olive Whistler, Black-faced Cuckoo-shrike and Golden Whistler.

Four other categories had too few birds too analyse. These were:

Bronzewing group: Brush Bronzewing

Lapwing group: Masked Lapwing

Falcon group: Australian Hobby and Brown Falcon

Swallow group: Tree Martin

See Appendix IV for numbers of each species by bird group. Daniels (2005) used similar bird groups to bird habitat relationships.

All native bird species and the same six categories as above were also compared with vegetation structure variables using one way ANOVA tests in Minitab. Vegetation variables were percent cover in the four height classes, total percent cover, number of vegetation layers, percent cover of leaf litter and dead wood and percent cover of bare soil. A table comparing the bird groups with vegetation variables was made using P-values and an indication as to whether there was a positive, negative or no correlation between the two variables.

2. Invertebrates

The raw data was entered into an excel sheet and a bar chart was created summarizing the average native and introduced invertebrate species richness and abundance per tree at each sampling location. Ordinations comparing the relationship of invertebrate species composition by the sampling location and the plant they occurred on were performed in PC Ord 4. Finally, a one tailed t-test comparing invertebrate abundance on native versus exotic plants was performed in Excel.

3. Human Disturbance:

The same six bird groups that were used for plant-bird relationships were compared with percent cover of built environment, amount of vehicle traffic, amount of pedestrian traffic and noise level using the same process as for vegetation structure (one way ANOVA tests in Minitab). A summary table showing P-value and an indication of a positive, negative or no correlation was used to compare bird groups with human disturbance variables.

4. Bird-habitat interactions

The six bird groups were used to assess behavioural interactions with habitat. All behaviours were shown in a in a pie chart showing proportion of birds exhibiting each behaviour to give an overview of the most commonly exhibited behaviours among all groups. Subsequently only habitat utilizing behaviours were included in a table showing the most to least commonly exhibited behaviour, and the percentage of each bird group exhibiting them with an emphasis on the six groups with over 100 individuals in them. Finally, the four bird groups with fewer than 100 individuals and all non habitat utilizing behaviours were excluded from a bar chart summarizing the percentage of individuals of the six bird groups exhibiting various habitat utilizing behaviours.

5. Bird response to seasons

Bird species were placed into four categories based on whether they were native or introduced and migratory or non-migratory and assessed for response to season within these categories. Categories were, by most to least number of species, native non-migratory (NNM), introduced non-migratory (INM), native summer migrant (NSM) and native altitudinal migrant (NAM). The first three surveys at each site were analysed as summer data (February 8^{th}- March 5^{th}) while the last three surveys were analysed as autumn data (March 7^{th}- April 10^{th}). Species were considered to show a preference for summer or autumn if they were more than 1.25 times more abundant in one season or the other, and to show no seasonal preference if they were not. With the exception of known summer migrant species which were not seen at all in autumn, species which had fewer than 10 individuals were excluded from classification because the probability that any seasonal preference was due to random chance due to few observations was high. A bar chart was used to display a comparison of the percentage of species in each of the four categories which favoured summer, favoured autumn, were neutral or had too few individuals to classify.

Chapter 4 Results

4.1 Question 1

What is the difference in bird diversity, abundance and species composition in a range of urban and urban fringe environments from highly disturbed to relatively pristine?

4.1.1 Diversity

A total of 50 species of birds were recorded across the five sites over the nine week study period, including 8 introduced species and 8 endemics. Of these 50, 44 were seen at the count points during survey periods and 6 were seen incidentally at the sites. The 6 species seen incidentally were used only for assessing relative species richness of the sites and were excluded for all other parts of the data analysis.

Species richness ranged widely across the sites and there was a threefold difference between the most and least diverse site (Figure 4.1). Knocklofty Reserve was the most species rich with a total of 31 species, 6 of which were endemic and 2 of which were introduced. The Queen's Domain was the second most species rich with a total of 29 species including 4 endemics and 6 introduced species. Bicentennial Park was next with 25 total, 6 endemic and 3 introduced followed by Sandy Bay with 23 total, 3 endemic and 7 introduced and finally Hobart with 10 total, no endemics and 5 introduced species.

The five sites had varying rates of species accumulation (Figure 4.2). Hobart was the first site to level off in species accumulation, reaching its final number of species by the fourth week. Sandy Bay was next and still showed a slow increase in species richness at the end of the study period but the rate of increase had slowed down dramatically. Bicentennial Park had begun to level off by week four, and then increased again in week five as the season changed before starting to level off again. The Queen's Domain increased rapidly in species richness in the first two weeks and slowly but steadily there after which probably would have continued if the study period were longer. Knocklofty Reserve was the only site that did not appear to be levelling off at all at the time the study period ended, and probably was considerably more species rich than this study indicates. It increased steadily for the first three weeks, levelled off a bit and then increased again over the last two weeks as autumn arrived.

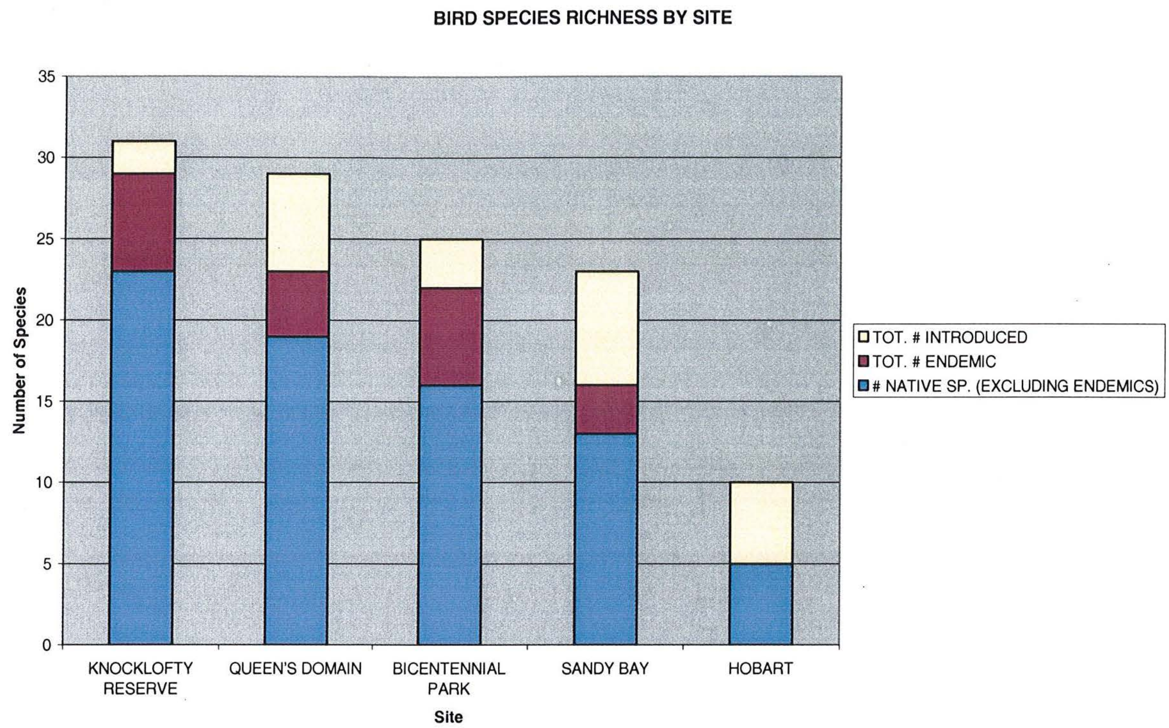


Figure 4.1: Total number of species by site broken down by number introduced, endemic and native non-endemic.

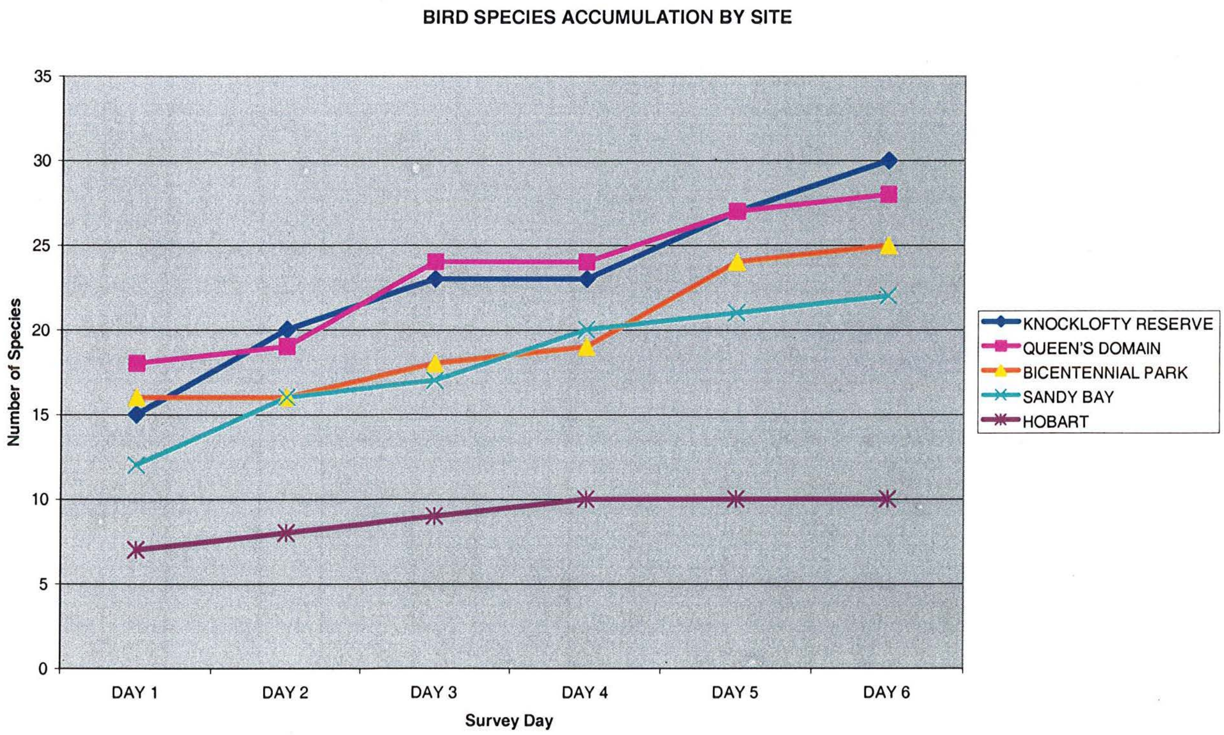


Figure 4.2: Species accumulation by site. Days 1-6 are the six survey days for each site. Note that days are not the same calender date for each site (e.g. day 1 is a different date for each site, etc.). See Table 3.1 for calender dates of surveys.

4.1.2 Abundance

Of the 44 species recorded at the count points, four of the five species with the highest average abundances across all five sites were introduced. These included the Rock Dove, House Sparrow, European Blackbird and Common Starling. The five most abundant native species (on average) were, from most to least abundant, the Brown Thornbill, Forest Raven, Yellow-throated Honeyeater, Spotted Pardalote and Silvereye. Masked Lapwings, Tasmanian Scrubwrens, Grey Butcherbirds, Strong-billed Honeyeaters, European Greenfinches, Australian Hobbies, Tree Martins, Yellow-tailed Black Cockatoos, Black-faced Cuckoo-shrikes, Tasmanian Thornbills and Golden Whistlers were the least abundant species, all with fewer than 10 individuals recorded overall (see Appendix III for a complete list of species in descending order by total and average abundances by site).

The average abundance per count point per survey day ranged by site from 4.99 at Bicentennial Park to 7.1 at Knocklofty Reserve (Figure 4.3). The more urbanized sites were in between with averages of 5.96 at Sandy Bay and 5.76 at Hobart. Finally, the Queen's Domain had an average of 5.15 individuals per count point per survey day. However, when separated by native and introduced individuals, Knocklofty Reserve had the highest average number native, followed by Bicentennial Park, the Queen's Domain, Sandy Bay and Hobart. When considered by broad habitat type (see Section 3.41 for description of broad habitat types), the results are similar to those by site, with the two urban habitat types having much higher average number of introduced individuals than the bushland habitat types.

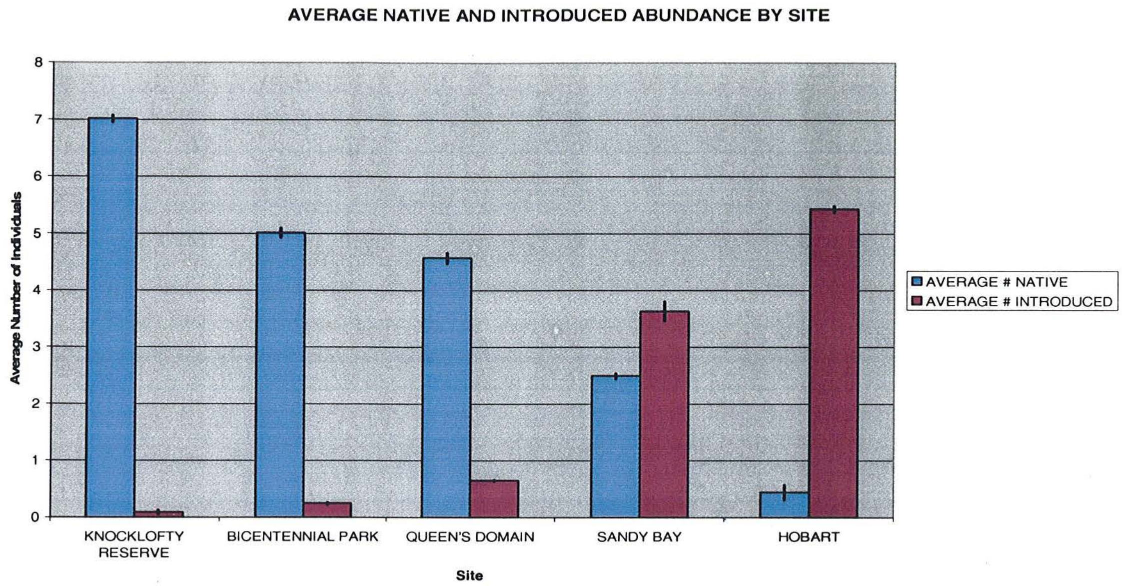


Figure 4.3: Average abundance of native and introduced individuals per count point per day by site with standard error bars.

4.1.3 Species composition

According to the species classification system (Section 3.4.1)., there were 29 woodland specialists, 8 woodland generalists, 2 generalists, 4 urban generalists and 7 urban specialists (Tables 4.1-4.3). Of the woodland specialists, 21 species were most abundant, 18 were most widespread and 19 occurred most frequently at Knocklofty woodland (of the five broad habitat types); 4 were most abundant, 5 were most widespread and 4 occurred most frequently at Bicentennial woodland; and 5 were most abundant, widespread and occurred most frequently at the Domain woodland. Of the woodland generalists, 4 were most abundant and 3 were most widespread and frequent at Knocklofty woodland, 2 were most widespread and frequently occurring at Bicentennial woodland; 3 were most abundant, widespread and frequently occurring at the Domain woodland and 1 occurred equally frequently at the Domain woodland and urban parks. The generalist species were most widespread at Bicentennial woodland but one was most abundant and occurred most frequently at urban parks while the other was most abundant and occurred most frequently at urban streets. All 4 urban generalists were most abundant, widespread and frequently occurring at urban parks. Four urban specialists were most abundant and 3 were most widespread and frequently occurring at urban parks while 3 were most abundant and 4 were most widespread and frequently occurring at urban streets.

AVERAGE ABUNDANCE PER PT. PER DAY BY BROAD HABITAT TYPE

SPECIES	KW	BW	DW	UP	US	AVERAGE	SPECIES TYPE
BRTH	**1.92**	1.59	0.40	0.00	0.00	0.78	WS
SPPA	**1.04**	0.36	0.14	0.01	0.00	0.31	WS
YEHO**	**0.90**	0.68	0.13	0.01	0.00	0.34	WS
BLHO**	**0.50**	0.11	0.00	0.03	0.00	0.13	WS
STPA	**0.28**	0.05	0.06	0.12	0.00	0.10	WS
GRCU	**0.16**	0.06	0.03	0.00	0.00	0.05	WS
GRRO**	**0.12**	0.05	0.00	0.05	0.00	0.04	WS
DUWO	**0.11**	0.00	0.00	0.00	0.00	0.02	WS
SUFA	**0.09**	0.06	0.00	0.02	0.00	0.03	WS
GRSH	**0.08**	0.06	0.00	0.00	0.00	0.03	WS
EASP	**0.08**	0.05	0.00	0.00	0.00	0.03	WS
SCRO	**0.08**	0.00	0.00	0.00	0.00	0.02	WS
STHO**	**0.06**	0.00	0.00	0.00	0.00	0.01	WS
YEBL	**0.03**	0.00	0.00	0.00	0.00	0.01	WS
BLCO	**0.03**	0.00	0.00	0.00	0.00	0.01	WS
GOWH	**0.02**	0.00	0.00	0.00	0.00	0.00	WS
BRFA	**0.02**	0.00	0.00	0.00	0.00	0.00	WS
BEFI	**0.00**	0.00	0.00	0.00	0.00	0.00	WS
DURO**	**0.00**	0.00	0.00	0.00	0.00	0.00	WS
FACO	**0.00**	0.00	0.00	0.00	0.00	0.00	WS
WESW	**0.00**	0.00	0.00	0.00	0.00	0.00	WS
BRBR	0.00	**0.26**	0.00	0.00	0.00	0.05	WS
TASC**	0.00	**0.06**	0.00	0.00	0.00	0.01	WS
OLWH	0.00	**0.01**	0.00	0.00	0.00	0.00	WS
MULO	0.00	0.00	**1.04**	0.00	0.00	0.21	WS
NOMI	0.00	0.00	**0.83**	0.00	0.00	0.17	WS
GRBU	0.02	0.00	**0.06**	0.00	0.00	0.02	WS
AUHO	0.00	0.00	**0.06**	0.01	0.00	0.01	WS
TATH**	0.00	0.00	0.00	**0.00**	0.00	0.00	WS
FOR A	**0.76**	0.42	0.47	0.16	0.09	0.38	WG
YEWA**	**0.32**	0.29	0.22	0.13	0.02	0.20	WG
GRFA	**0.19**	0.16	0.00	0.05	0.00	0.08	WG
LAKO*	**0.08**	0.03	0.00	0.02	0.00	0.03	WG
EARO	0.00	0.00	**0.67**	0.23	0.00	0.18	WG
AUMA	0.03	0.00	**0.47**	0.13	0.01	0.13	WG
EUGL*	0.00	0.09	**0.10**	0.03	0.00	0.04	WG
SUCO	0.00	0.12	0.00	0.04	**0.12**	0.05	WG
NHHO	0.02	0.08	0.00	**0.21**	0.04	0.07	G
SIEY	0.14	0.33	0.00	0.20	**0.59**	0.25	G
EUBL*	0.01	0.14	0.00	**0.91**	0.59	0.33	UG
LIWA	0.00	0.17	0.00	**0.64**	0.16	0.19	UG
MALA	0.00	0.00	0.03	**0.05**	0.00	0.02	UG
CRHO	0.00	0.00	0.00	**0.01**	0.00	0.00	UG
RODO*	0.00	0.00	0.42	**1.60**	0.56	0.51	US
SPTU*	0.00	0.00	0.00	**0.29**	0.06	0.07	US
TRMA	0.00	0.00	0.00	**0.04**	0.00	0.01	US
RALO	0.00	0.00	0.00	**0.00**	0.00	0.00	US
HOSP*	0.00	0.00	0.00	0.62	**1.92**	0.51	US
COST*	0.00	0.00	0.13	0.49	**0.98**	0.32	US
EUGR*	0.00	0.00	0.00	0.00	**0.05**	0.01	US

Table 4.1

PROPORTION OF PTS SPECIES IS FOUND IN BY BROAD HABITAT TYPE

SPECIES	KW	BW	DW	UP	US	PROP. OF PTS FOUND IN	SPECIES TYPE
YEHO**	**1**	**1**	0.5	0.06	0	0.49	WS
SPPA	**0.93**	0.85	0.33	0.06	0	0.4	WS
STPA	**0.53**	0.31	0.17	0.12	0	0.22	WS
GRCU	**0.4**	0.23	0.08	0	0	0.13	WS
GRSH	**0.4**	0.23	0	0	0	0.12	WS
EASP	**0.4**	0.23	0	0	0	0.12	WS
BLHO**	**0.33**	0.15	0	0.06	0	0.11	WS
SCRO	**0.27**	0	0	0	0	0.05	WS
SUFA	**0.13**	0.08	0	0.06	0	0.05	WS
BLCO	**0.13**	0	0	0	0	0.03	WS
GOWH	**0.13**	0	0	0	0	0.03	WS
YEBL	**0.07**	0	0	0	0	0.01	WS
STHO**	**0.07**	0	0	0	0	0.01	WS
DUWO	**0.07**	0	0	0	0	0.01	WS
BRFA	**0.07**	0	0	0	0	0.01	WS
BEFI	**0**	0	0	0	0	0	WS
DURO**	**0**	0	0	0	0	0	WS
WESW	**0**	0	0	0	0	0	WS
BRTH	0.93	**1**	0.5	0	0	0.45	WS
BRBR	0	**0.54**	0	0	0	0.09	WS
GRRO**	0.07	**0.23**	0	0.06	0	0.07	WS
TASC**	0	**0.23**	0	0	0	0.04	WS
OLWH	0	**0.08**	0	0	0	0.01	WS
MULO	0	0	**0.83**	0	0	0.18	WS
NOMI	0	0	**0.75**	0	0	0.15	WS
GRBU	0.13	0	**0.25**	0	0	0.07	WS
AUHO	0	0	**0.17**	0.06	0	0.04	WS
TATH**	0	0	0	**0.06**	0	0.01	WS
FOR A	**0.93**	0.92	0.67	0.47	0.41	0.65	WG
YEWA**	**0.73**	0.62	0.58	0.29	0.12	0.43	WG
LAKO*	**0.27**	0.15	0	0.12	0	0.11	WG
GRFA	0.4	**0.46**	0	0.12	0	0.19	WG
SUCO	0	**0.23**	0	0.12	0.06	0.08	WG
AUMA	0.2	0	**0.83**	0.12	0.12	0.22	WG
EARO	0	0	**0.5**	0.29	0	0.18	WG
EUGL*	0	0.15	**0.17**	0.12	0	0.08	WG
SIEY	0.27	**0.46**	0	0.18	0.41	0.31	G
NHHO	0.07	**0.31**	0	0.18	0.12	0.13	G
EUBL*	0.07	0.38	0	**0.76**	0.53	0.39	UG
LIWA	0	0.46	0	**0.53**	0.35	0.28	UG
MALA	0	0	0.08	**0.12**	0	0.04	UG
CRHO	0	0	0	**0.06**	0	0.01	UG
TRMA	0	0	0	**0.12**	0	0.03	US
RALO	0	0	0	**0**	0	0	US
SPTU*	0	0	0	**0.41**	**0.41**	0.18	US
HOSP*	0	0	0	0.35	**1**	0.31	US
COST*	0	0	0.17	0.47	**0.88**	0.34	US
RODO*	0	0	0.17	0.23	**0.29**	0.16	US
EUGR*	0	0	0	0	**0.06**	0.01	US

Table 4.2

AVERAGE PERCENTAGE FREQUENCY OF OCCURRENCE BY BROAD HABITAT TYPE

SPECIES	KW	BW	DW	UP	US	AVERAGE %	SPECIES TYPE
YEHO**	**66.67**	57.69	12.50	0.98	0.00	27.57	WS
BRTH	**46.67**	42.31	12.50	0.00	0.00	20.29	WS
SPPA	**52.22**	32.05	11.11	0.98	0.00	19.27	WS
STPA	**20.00**	5.13	4.17	2.94	0.00	6.45	WS
BLHO**	**11.11**	2.56	0.00	0.98	0.00	2.93	WS
GRCU	**8.89**	3.85	1.39	0.00	0.00	2.82	WS
EASP	**6.67**	3.85	0.00	0.00	0.00	2.10	WS
GRSH	**6.67**	5.13	0.00	0.00	0.00	2.36	WS
SCRO	**5.56**	0.00	0.00	0.00	0.00	1.11	WS
SUFA	**4.44**	1.28	0.00	0.98	0.00	1.34	WS
BLCO	**2.22**	0.00	0.00	0.00	0.00	0.44	WS
GOWH	**2.22**	0.00	0.00	0.00	0.00	0.44	WS
BRFA	**1.11**	0.00	0.00	0.00	0.00	0.22	WS
DUWO	**1.11**	0.00	0.00	0.00	0.00	0.22	WS
STHO**	**1.11**	0.00	0.00	0.00	0.00	0.22	WS
YEBL	**1.11**	0.00	0.00	0.00	0.00	0.22	WS
BEFI	**0.00**	0.00	0.00	0.00	0.00	0.00	WS
DURO**	**0.00**	0.00	0.00	0.00	0.00	0.00	WS
WESW	**0.00**	0.00	0.00	0.00	0.00	0.00	WS
BRBR	0.00	**20.51**	0.00	0.00	0.00	4.10	WS
GRRO**	2.22	**3.85**	0.00	2.94	0.00	1.80	WS
TASC**	0.00	**6.41**	0.00	0.00	0.00	1.28	WS
OLWH	0.00	**1.28**	0.00	0.00	0.00	0.26	WS
NOMI	0.00	0.00	**34.72**	0.00	0.00	6.94	WS
MULO	0.00	0.00	**29.17**	0.00	0.00	5.83	WS
GRBU	2.22	0.00	**5.56**	0.00	0.00	1.56	WS
AUHO	0.00	0.00	**4.17**	0.98	0.00	1.03	WS
TATH**	0.00	0.00	0.00	**0.17**	0.00	0.03	WS
FOR A	**43.33**	33.33	18.06	10.78	6.86	22.47	WG
YEWA**	**22.22**	17.95	16.67	9.80	1.96	13.72	WG
LAKO*	**5.56**	2.56	0.00	1.96	0.00	2.02	WG
GRFA	12.22	**12.82**	0.00	4.90	0.00	5.99	WG
SUCO	0.00	**5.13**	0.00	2.94	1.96	2.01	WG
EARO	0.00	0.00	**29.17**	7.84	0.00	7.40	WG
AUMA	3.33	0.00	**25.00**	5.88	0.98	7.04	WG
EUGL*	0.00	2.56	**4.17**	0.98	0.00	1.54	WG
NHHO	2.22	6.41	0.00	**9.80**	2.94	4.28	G
SIEY	4.44	12.82	0.00	5.88	**16.67**	7.96	G
EUBL*	1.11	10.26	0.00	**42.16**	29.41	16.59	UG
LIWA	0.00	12.82	0.00	**38.24**	13.73	12.96	UG
MALA	0.00	0.00	1.39	**2.94**	0.00	0.87	UG
CRHO	0.00	0.00	0.00	**0.98**	0.00	0.20	UG
SPTU*	0.00	0.00	0.00	**14.71**	5.88	4.12	US
TRMA	0.00	0.00	0.00	**1.96**	0.00	0.39	US
RALO	0.00	0.00	0.00	**0.00**	0.00	0.00	US
HOSP*	0.00	0.00	0.00	13.73	**58.82**	14.51	US
COST*	0.00	0.00	2.78	15.69	**39.22**	11.54	US
RODO*	0.00	0.00	2.78	13.73	**16.67**	6.63	US
EUGR*	0.00	0.00	0.00	0.00	**0.98**	0.20	US

Table 4.3

Tables 4.1-4.3: Species classification by average abundance, how widespread they are and frequency of occurrence, respectively, at five broad habitat types. KW= Knocklofty woodland, BW= Bicentennial woodland, DW= Domain woodland, UP= urban parks and US= urban streets). Different Colours denote habitat preferences. WS= woodland specialist (blue), WG=woodland generalist (green), G= generalist (yellow), UG= urban generalist (orange) and US= urban specialist (pink). See Section 3.4.1 for definitions of the five species classifications. Bold numbers denote which broad habitat type has the highest average abundance, degree of widespreadness or frequency of occurrence of a given species.

Of the five broad habitat types, Knocklofty woodland and Bicentennial woodland had similar bird species compositions, urban parks and urban streets had similar bird species compositions and the Domain woodland was unique in bird species composition (Figure 4.4). Species which most characterized Knocklofty woodland and Bicentennial woodland included Spotted Pardalotes, Grey Currawongs, Brown Thornbills, Yellow-throated Honeyeaters, Grey Shrike-thrushes, Eastern Spinebills, Laughing Kookaburras, Superb Fairywrens, Grey Fantails and Forest Ravens. Black-headed Honeyeaters, Striated Pardalotes, Green Rosellas and Scarlet Robins also occurred at both reserves, but occurred elsewhere as well. A number of species were found only at Knocklofty Reserve, including Dusky Wood-swallows, Black-faced Cuckoo-shrikes, Golden Whistlers, Brown Falcons, Beautiful Firetails, Dusky Robins and Fan-tailed Cuckoos (the last three seen incidentally). The Domain woodland was most characterized by Musk Lorikeets, Noisy Miners, Grey Butcherbirds, Eastern Rosellas, Australian Hobbies and Forest Ravens, but some of the afore mentioned woodland birds occurred there as well. Urban parks and urban streets were best characterized by New Holland Honeyeaters, European Blackbirds, Common Starlings, Little Wattlebirds, Spotted Turtle-doves, Tree Martins, Crescent Honeyeaters, Rock Doves and Masked Lapwings. Other species such as Forest Ravens occurred in the urban habitats in small numbers.

When broken down into 11 more fine scale habitat types, all woodland habitats had similar bird species compostions including the one at the Queen's Domain, all urban habitats had similar bird species compositions except the Queen's Domain parks which were unique in bird species composition (Figure 4.5). The Queen's Domain grassland habitat was also unique. Woodland and urban habitats were largely still characterized by the same species as in the broad habitat types and the species which characterized the Queen's Domain were shown to be specific to its grassland habitat. The Queen's Domain Parks had a species composition in between that of the urban and woodland habitats.

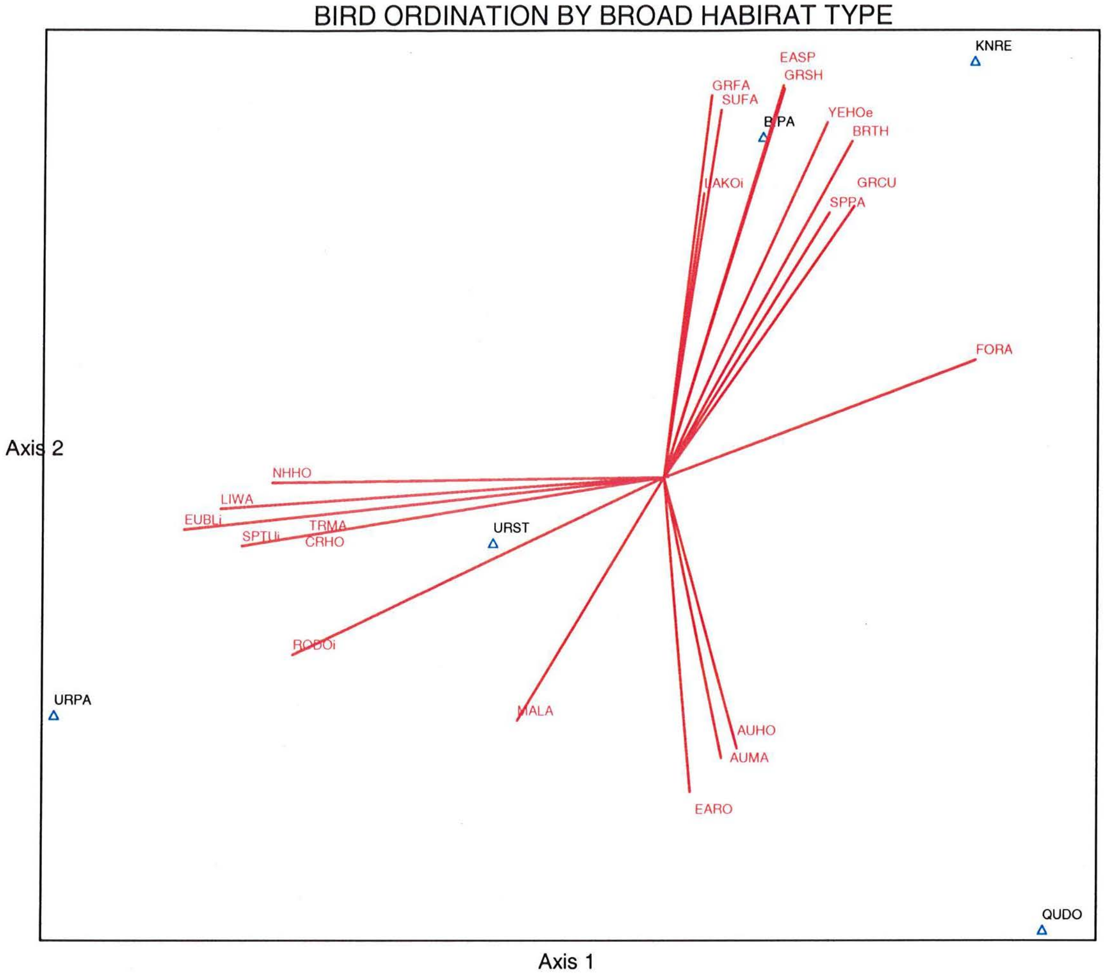


Figure 4.4: Ordination (NMS) showing the association of broad habitats based upon occurrences of bird species. Stress in 3 dimensions = 0.001. Cut-off level for r2 is 0.600. KNRE= Knocklofty Reserve woodland, BIPA= Bicentennial Park woodland, QUDO= Queen's Domain woodland, URST= Urban Streets and URPA= Urban Parks. For species codes see Appendix II.

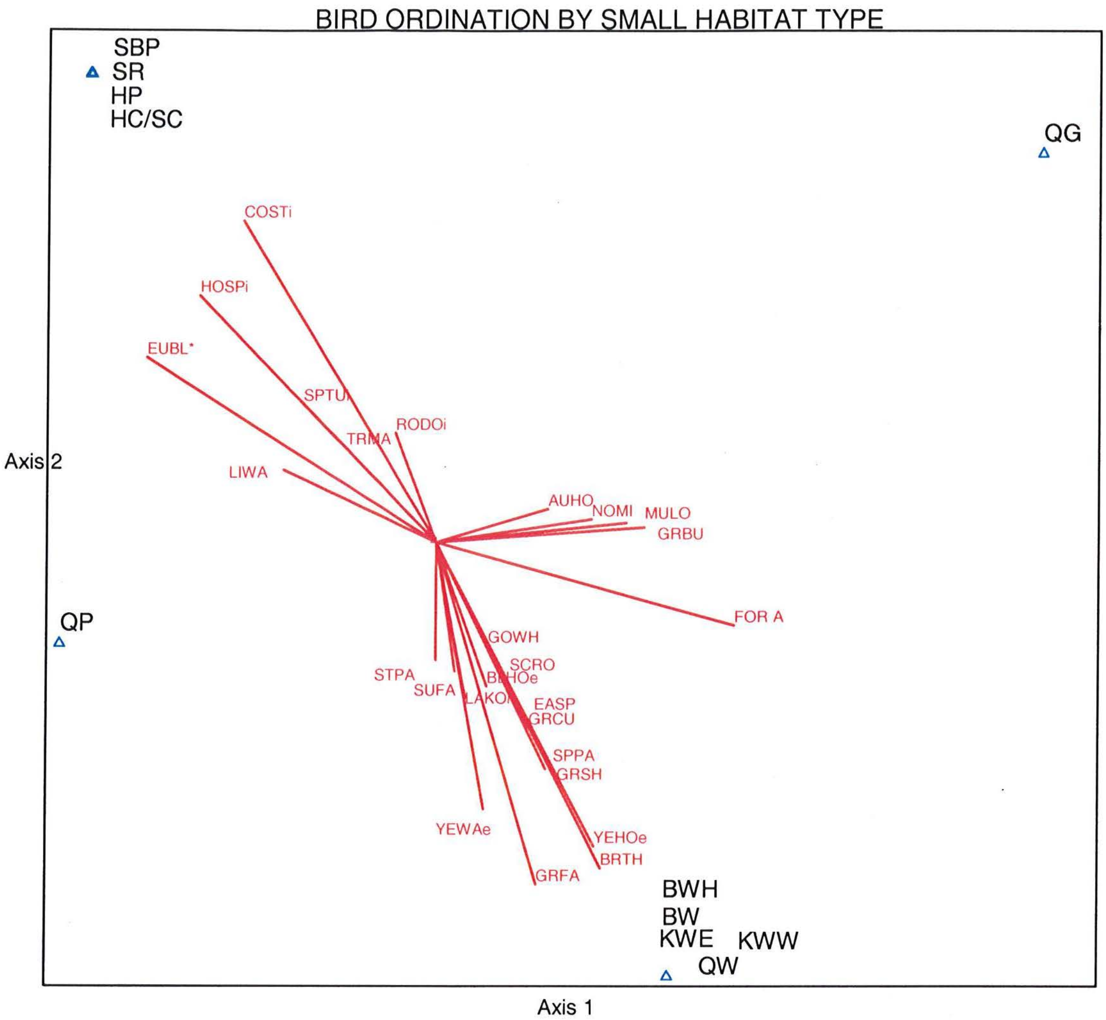


Figure 4.5: Ordination (NMS) showing the sample sites based upon average bird numbers. Stress in 3 dimensions = 0.00436. Cut-off level for r2 is 0.200. For species codes see Appendix II. HC/SC= Hobart/Sandy Bay commercial streets, SR= Sandy Bay residential streets, HP= Hobart parks, SBP= Sandy Bay parks, QP= Queen's Domain exotic sites, QG= Queen's Domain grassland, QW= Queen's Domain dry woodland, BWH= Bicentennial Park wet forest, BW= Bicentennial Park dry woodland, KWE= Knocklofty Reseve dry woodland east slope, KWW= Knocklfoty Reserve dry woodland west slope.

4.2 Question 2

Is there a greater diversity and abundance of native birds and fewer exotic birds in urban and/or native vegetation remnant parks than in surrounding urban streetscapes?

As a whole, native vegetation sites had more native species than urban sites as measured by the mean number of native species recorded per count point. At native vegetation count points the mean number of species was 8.08 with a variance of 6.01 and at urban count points it was 2.39 with a variance of 5.25. This difference in mean was very highly statistically significant as the P-value was well below 0.001 (Table 4.4).

In addition, urban parks as a whole had more native species than urban streets when measured in the same way as previously mentioned. The mean number of native species at urban parks was 3.44 with a variance of 6.93 and at urban streets it was 1.14 with a variance of 1.88. This difference in mean was also highly statistically significant with a P-value of 0.004.

Urban parks had more native species on average than their adjacent urban streets, but less than adjacent woodland sites. For example, Hobart Parks had a mean number of native species of 1.33 with a variance of 0.23 and Hobart Streets had a mean number of 0.5 with a variance of 0.29. However, this difference in mean was not statistically significant. Sandy Bay Parks had a mean number of native species of 4.33 with a variance of 2.71 while Sandy Bay Streets had a mean number of native species of 2.67 with a variance of 1.24, which was a statistically significant difference. Finally, the Queen's Domain Urban Parks had a mean of 5.2 with a variance of 6.7 while surrounding grassland habitat had a mean of 6.4 and a variance of 2.3 and surrounding woodland habitat had a mean of 7 with a variance of 6.71. The differences in mean between the Queen's Domain parks and surrounding native habitats was not statistically significant but nevertheless suggest that native habitats tend to have more native species than urban parks.

Locations	n	Mean	Variance	df	t-value	P-value
All Urban Pts	33	2.39	5.25			
All Bushland Pts	40	8.08	6.02	71	-10.14	9.381E-16***
All Parks	16	3.44	6.93			
All Streets	17	1.14	1.88	31	2.8	.004**
H. Parks	6	1.33	.2.27			
H. Streets	8	.5	.286	12	1.46	.08
SB Parks	6	4.33	2.71			
SB Streets	7	2.67	1.24	11	2.12	.03*
QD Parks	5	5.2	6.7			
QD Grassland	5	6.4	2.3	8	-0.89	0.2
QD Parks	5	5.2	6.7			
QD Woodland	7	6.71	2.57	10	-1.26	0.12

Table 4.4: One-tailed t-tests comparing mean native species richness between all urban count points and all bushland count points, all parks and all urban streets, Hobart parks and streets, Sandy Bay parks and streets, Queen's domain parks and grassland and Queen's Domain parks and woodland. * denotes statistical significance, *= $P<0.05$, **= $P<0.01$ and ***= $P<0.001$.

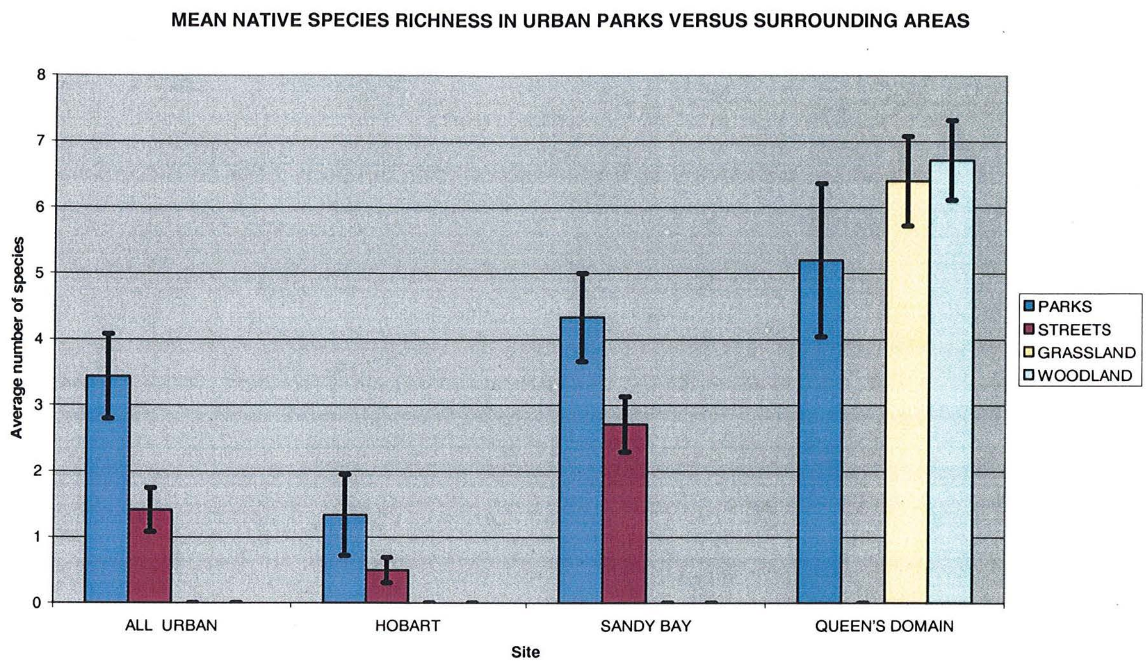


Figure 4.6: Mean native species richness at all parks vs. streets, Hobart parks vs. Hobart streets, Sandy Bay parks vs. Sandy Bay streets and Queen's Domain parks vs. Queen's Domain grassland and woodland habitats. Black bars are standard error bars.

4.3 Question 3

Does variation in native and exotic bird diversity and abundance correlate strongly to variation in vegetation, invertebrates and/or degree of human disturbance across the range of urban habitats?

4.3.1 Plants

Species Richness and Composition:

A total of 286 plant species were found, including 152 introduced species, 107 native non-endemics, 17 mainland natives and 10 endemic species (Appendix V). Urban parks and urban streets were more species rich than any of the three native sites but Knocklofty woodland had the highest number of native plant species, followed by Bicentennial woodland, the Domain woodland, urban streets and parks. Bicentennial woodland had the highest number of endemic plant species (7), followed by Knocklofty woodland (4), the two urban sites (3 and 2) and the Domain woodland (1). The woodland habitats had very few mainland native species but the urban habitats had 17 (urban streets) and 7 (urban parks). Both urban habitat types had very high numbers of introduced plants ranging from 78 (urban parks) and 99 (urban streets) while the woodland habitats had only between 7 (Bicentennial) and 18 (Domain) (Figure 4.7).

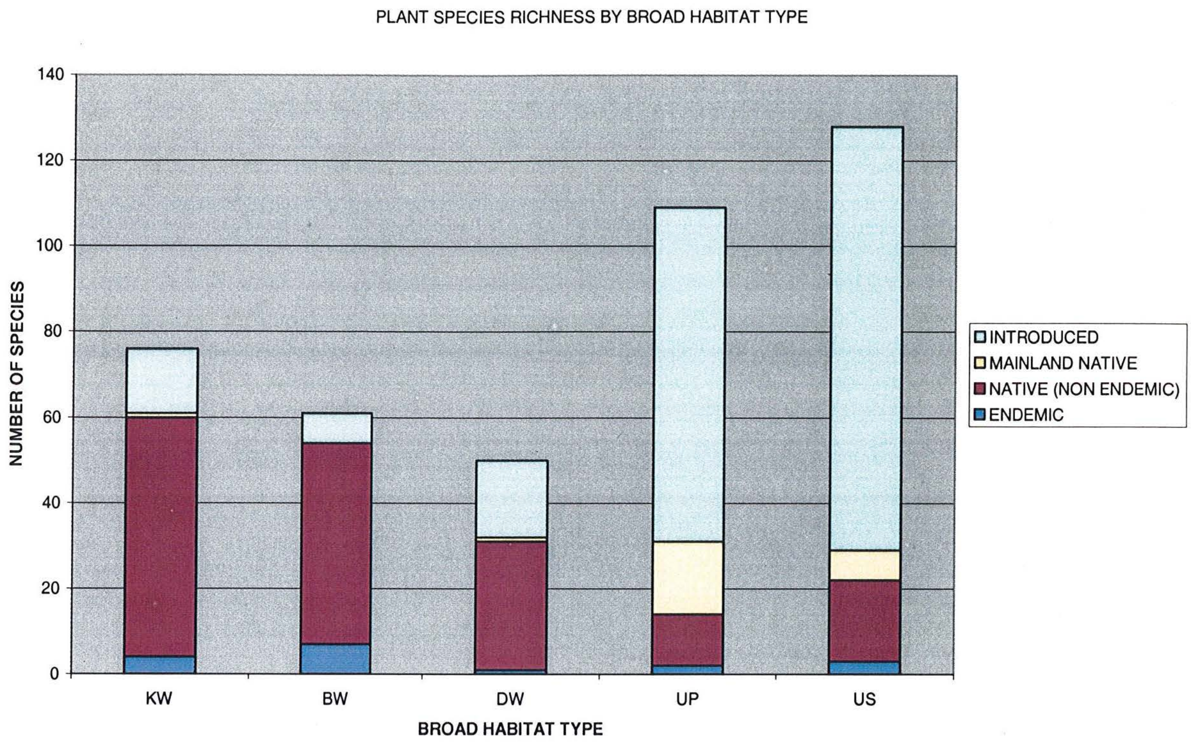


Figure 4.7: Plant species richness by broad habitat type broken down by endemic, native non-endemic, mainland native and introduced species. KW= Knocklofty woodland, BP= Bicentennial woodland, DW= Domain woodland, UP= urban parks, US= urban streets.

The three native woodland habitats were related and the two urban habitats were similar in plant species composition but there was a large difference between urban and woodland habitat types (Figure 4.8). In general, urban habitats varied more in species composition than woodland habitats did. Knocklofty woodland was most characterized by *Lomandra longifolia, Eucalyptus globulus, Eucalyptus pulchella, Poa rodwayi, Austrodanthonia* spp., *Centaurium erythraea** and *Senecio quadridentatus* as these species occurred most frequently there. *Bursaria spinosa, Austrostipa* spp., *Acacia dealbata, Juncus* spp., *Taraxacum officinale*, Beyeria viscosa, Dodonaea viscosa, Astroloma humifusum* and *Eucalyptus ovata* occurred most frequently at Bicentennial woodland. At the Domain woodland the most frequently occurring species were *Themeda triandra, Plantago lanceolata, Eucalyptus viminalis, Acaena echinata, Urospermum dalechampii*, Lepidosperma laterale, Dactylus glomerata*, Allocasuarina verticillata* and *Acacia genistifolia.* In urban parks, *Eucalyptus* spp. (M), *Clematis* spp.*, *Leptospermum grandifolium* and *Sambucus* spp.* were most widespread. Finally, *Foeniculum vulgare*, Helleborus* spp.*, *Hordeum vulgare*,* *Felicia amelloides** and *Poa annua** occurred most commonly in urban streets (Appendix V).

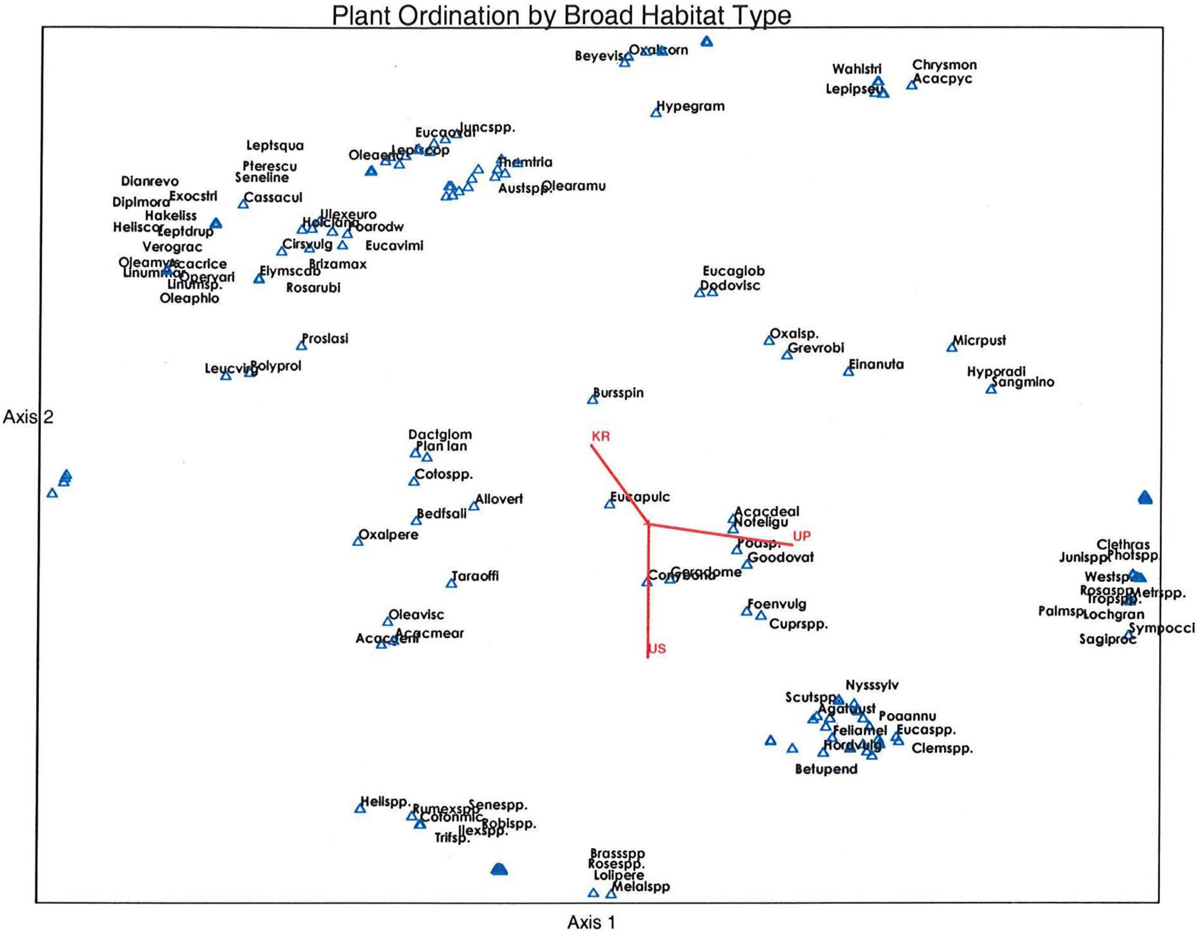


Figure 4.8: Plant ordination by broad habitat type in two dimensions. Cut-off point is 0.200. Plant species abbreviations are first four letters of genus and species. KR= Knocklofty woodland, UP= urban parks, US= urban streets.

Relationship to Birds:

Native birds as a whole, the thornbill and honeyeater groups were all positively correlated in species richness with native plant species richness based on r-squared values (see Table 4.5). All the other native bird groups were also positively correlated with native plant species richness as well to a lesser extent. All native species groups were negatively correlated with introduced plant species richness and were not strongly correlated with mainland native plants in either a positive or negative direction. Exotic bird species richness was strongly negatively correlated with native plant species richness and positively correlated with introduced plant species richness. It was also positively correlated with mainland native plants species richness (see Appendix IV for bird group species and numbers).

	All Native Species	Exotic Group	Thornbill Group	Honey -eater Group	Rosella Group	Corvid Group	Thrush Group
N. Plants	.686*	-.726*	.621*	.586*	.090	.438	.281
I. Plants	-.496	.697*	-.414	-.338	-.067	-.388	-.252
MN Plants	-.069	.271	-.176	.100	.089	-.070	-.011

Table 4.5: Correlations between bird group species richness and native, introduced and mainland native plant species richness. * = strongest correlations. Numbers are r-squared values.

Native species richness was positively related to middle-storey, understorey, ground layer and total percent vegetation cover, number of vegetation layers, leaf litter percent cover and soil percent cover based on P-values (Table 4.6). In the thornbill and honeyeater groups, species richness was also positively related these variables. Exotic bird species richness was negatively related these variables. In the corvid group species richness was positively related to ground layer and total percent cover of vegetation and percent cover of leaf litter. In the thrush group species richness was positively related to middle-storey, ground layer and total vegetation percent cover. Other relationships existed as well, but they were not statistically significant, e.g. the rosella group. When bird abundance was used instead of species richness, the same relationships were found but less strongly.

	All Native Species	Exotic Group	Thornbill Group	Honey-eater Group	Rosella Group	Corvid Group	Thrush Group
Over-Storey	.256 (+)	.309 (0)	.767 (0)	.731 (+)	.07 (0)	.354 (0)	.77 (+)
Middle-Storey	.000 (+)***	.000 (-)***	.000 (+)***	.000 (+)***	.07 (-)	.539 (0)	.002 (+)**
Under-Storey	.005 (+)***	.016 (-)*	.004 (+)**	.001 (+)**	.831 (0)	.307 (0)	.263 (0)
Ground	.000 (+)***	.000 (-)***	.02 (+)*	.000 (+)***	.371 (+)	.006 (+)**	.002 (+)**
Veg. % Cover	.000 (+)***	.000 (-)***	.000 (+)***	.000 (+)***	.24 (+)	.001 (+)**	.013 (+)*
No. of Layers	.000 (+)***	.016 (-)	.011 (+)*	.001 (+)**	.184 (+)	.18 (+)	.292 (+)
Leaf litter	.000 (+)***	.000 (-)***	.000 (+)***	.000 (+)***	.028 (0)*	.001 (+)**	.000 (0)***
Soil	.000 (+)***	.009 (-)**	.000 (+)***	.007 (0)**	.271 (-)	.07 (+)	.000 (0)***

Table 4.6: Relationships between bird group species richness and vegetation structure and percent cover. Numbers are P-values; *= P<0.05, **= P<0.01 and ***= P<0.001. (-) denotes a negative, (+) denotes a positive and (0) denotes no relationship.

4.3.2 Invertebrates

A total of 107 species of invertebrates were collected from 73 trees and shrubs. These 107 species represented 19 orders and approximately 71 families (Appendix VI and VII). However, it should be noted that Hobart only had data from one location because samples were lost or not completed due to lack of time. Coleoptera (30 species), Araneae (18 species), Hemiptera (11 species), Hymenoptera (11 species), Lepidoptera (9 species) and Diptera (7 species) were the most well represented orders, representing 80.37% of the total number of species. Acarina (3 species), Collembola (3 species), Diplopoda (3 species), Nueroptera (2 species) and Thysanoptera (2 species) were the other orders with more than one species, representing another 12.15% of the total. Blattodea, Isopoda, Mollusca, Opiliones, Pseudoscorpionida, Psocoptera, Scorpionida and Thysanura each had only one species (Figure 4.9).

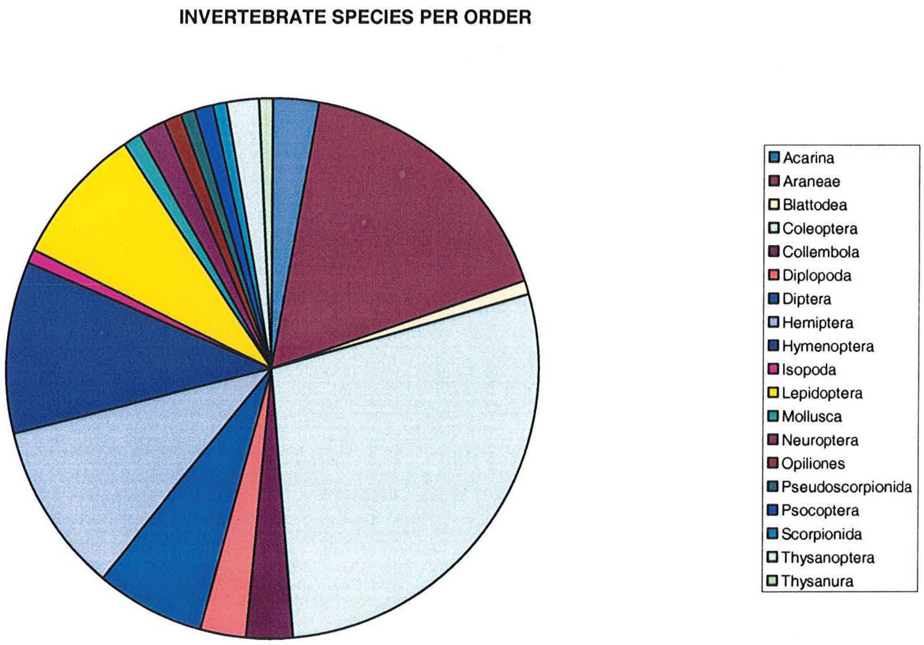


Figure 4.9: Pie chart depicting number of species per invertebrate order.

Average species richness per plant at the nine sampling locations (see section 3.3.2 for an explanation of sampling locations) ranged only from 1.75 to 5 species (Figure 4.10). Average abundance at the sampling locations ranged from 4 to 13 individuals per plant. Sandy Bay location 1 had the highest mean invertebrate abundance and the second highest mean invertebrate species richness, but a large portion of the abundance was introduced Argentine ants. Both mean native species richness and abundance per plant were highest at the Knocklofty location 2 sampling location. The Queen's Domain sampling location 1 (grassland) was the third most species rich on average but the fourth highest in average abundance per plant, and the Hobart sampling location was the reverse of that. The Queen's Domain location 2 had the fifth highest species richness and the sixth highest abundance per plant, after Sandy Bay location 2. Bicentennial Park location 1 (dry woodland) followed the Queen's Domain in average species richness and abundance per plant, followed closely by Bicentennial Park location 2 (wet woodland). Finally, Knocklofty location 1 and Sandy Bay location 1 had the lowest average species richness and Knocklofty location 1 had the lowest average abundance per plant.

Only 4 of the 107 species were introduced including *Bombus terrestris* (European bumblebee), *Linepithema humile* (Argentine ant), *Porcellio* sp. (slater or potato bug) and a species from the aphid family (see Figure 4.10). Introduced species were absent from the two Knocklofty sampling locations, one Bicentennial Park location and one Queen's Domain location (grassland). There was one introduced species at the other Queen's Domain location (*Porcellio* sp.), two at each of the Sandy Bay locations (*Linepithema humile* at both, the aphid species at one and *Porcellio* sp. at the other) and Hobart (*Linepithema humile* and *Bombus terrestris*). Introduced species were most abundant at Sandy Bay (nearly half the average abundance there), largely due to the large number of Argentine ants found.

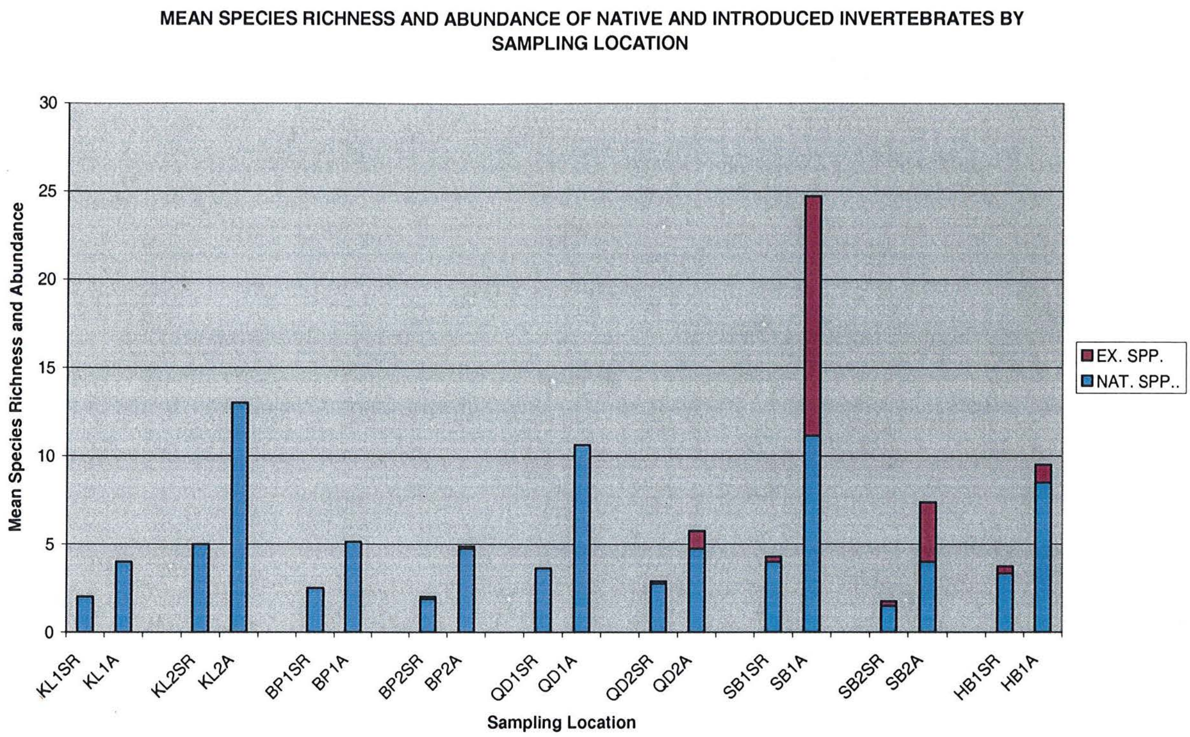


Figure 4.10: Mean invertebrate species richness and abundance per plant by sampling location. SR= species richness, A= abundance.

Invertebrate species composition on trees and shrubs were roughly associated by site and plant species (Figures 4.11 and 4.12). Sandy Bay and the Queen's Domain trees and shrubs were the most closely associated by site. Bicentennial Park and Knocklofty Reserve trees and shrubs were somewhat less closely associated with each other and Hobart trees and shrubs were the least closely associated in species composition of the five sites. Invertebrate species composition was also loosely associated by the tree or shrub species they were found on. *Eucalyptus, Bursaria, Melaluca* and to a lesser extent *Acacia* plants had invertebrate species assemblages which were loosely associated to each other. Other plant species had to few sampled to assess any potential pattern (see Appendix VII for invertebrate species codes).

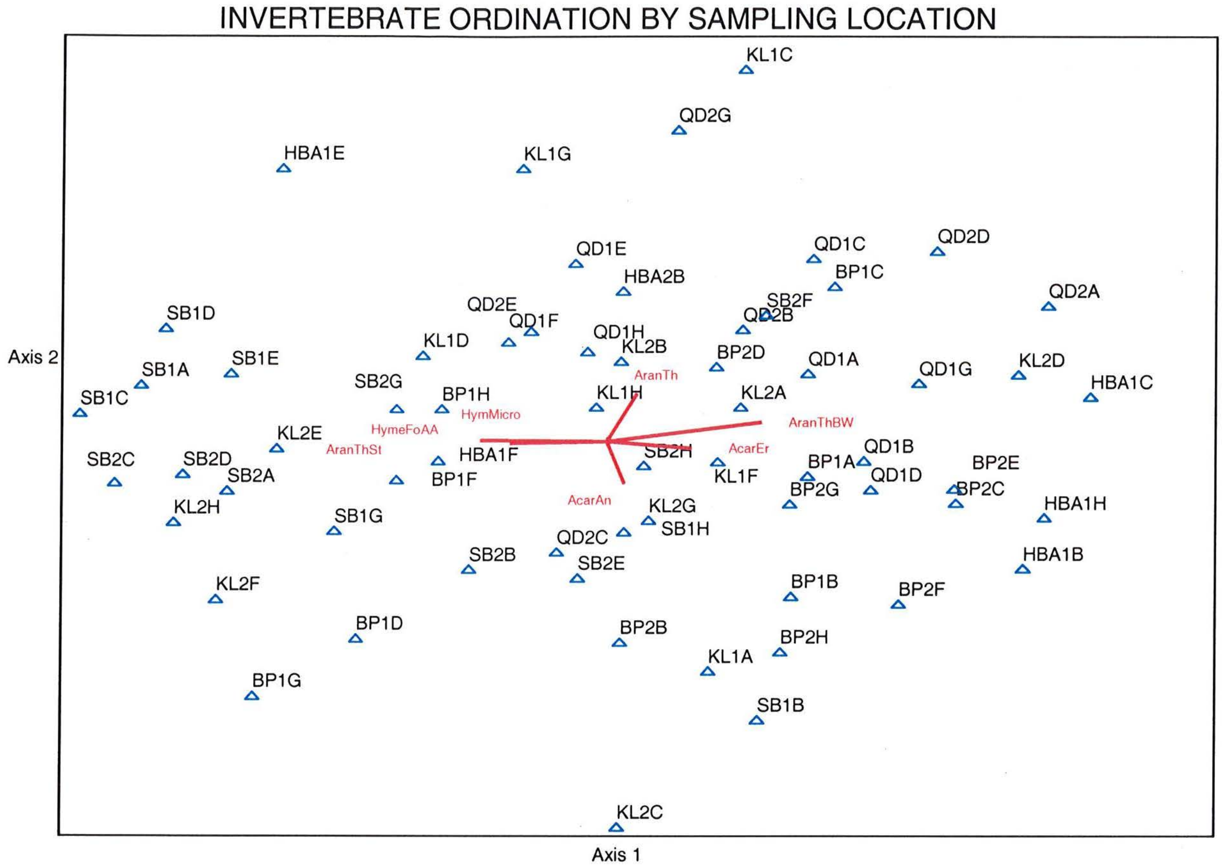


Figure 4.11: Ordination of sampling location based on invertebrate taxa in 3 dimensions, cut-off pt. is 0.200. See Methods 3.3.2 for explanation of sampling location letters and numbers (black text), Appendix VI for plant species of each location, and Appendix VII for invertebrate species codes (red text).

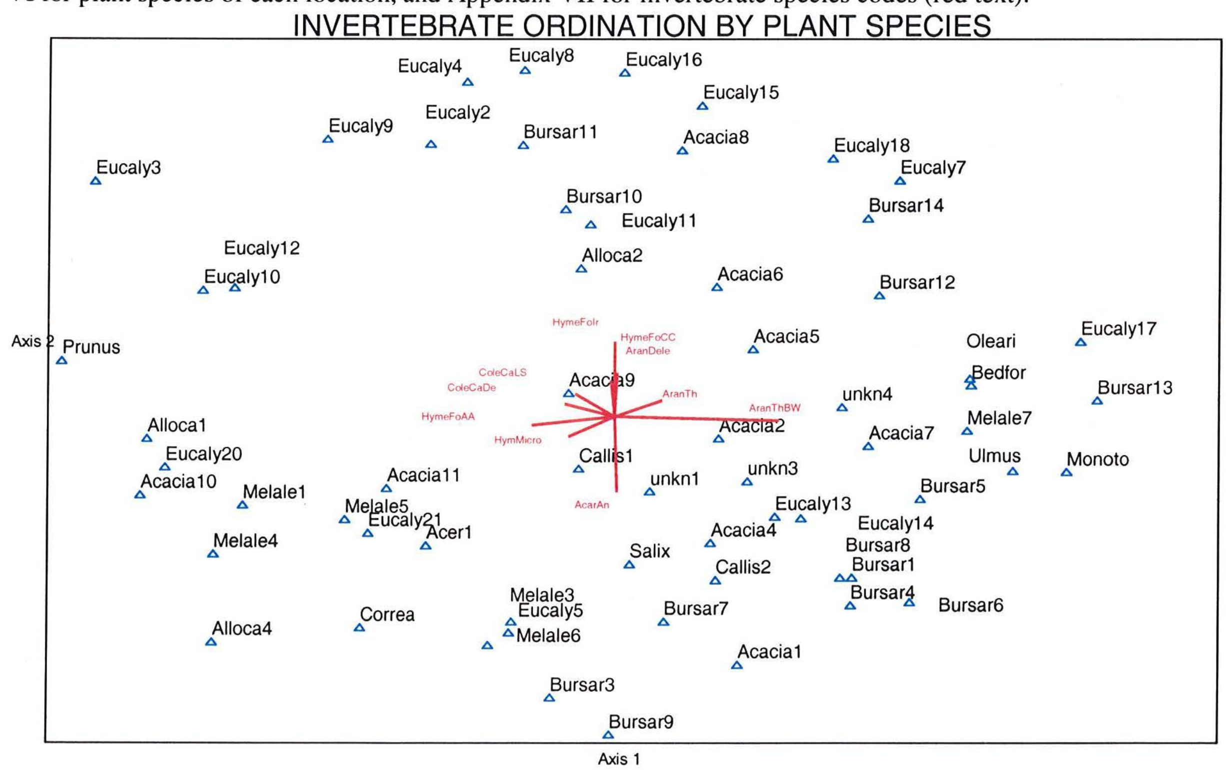


Figure 4.12: Ordination of plant species based on invertebrate taxa in 3 dimensions, cutoff pt is 0.200. Plant species names (black text) are abbreviated to first 5-6 letters of the genus and numbered. See Appendix VII for invertebrate species codes (in red).

4.3.3 Human Disturbance

Relationships between bird group species richness and human disturbance variables were almost all significant (Table 4.7). Native species as a whole and all native species bird groups except the rosella group were negatively correlated to all human disturbance variables. The negative correlations were the strongest for native species as a whole, and the thornbill group. The rosella group had no relationship to pedestrian traffic and a non-significant negative relationship to vehicle traffic. Exotic bird species richness was strongly positively correlated to all human disturbance variables. It is also worth noting that when bird abundance was used instead of species richness, the same relationships were found but less strongly.

Only habitat utilizing behaviours (see Section 3.4.3 (4) for definition of habitat utilizing behaviours) were included in all further analysis. The six bird groups with more than 100 individuals are the main basis for analysis and treated separately from the four groups with very low abundances.

Of the six major groups, the thrush group had the highest percentage of individuals perching in native trees (which was the most common habitat utilizing behaviour overall), but all the other major native bird groups had a high percentage of individuals perching in native trees as well (Table 4.8 and Figure 4.14). Only the introduced group perched in native trees very little. It is also worth noting that almost all falcons recorded were perched in native trees.

Of the six major groups, the introduced group was most frequently recorded foraging on the ground with the corvid group the next most frequently recorded foraging on the ground. The remaining native groups were infrequently recorded foraging on the ground. In the less abundant groups, all lapwings seen were foraging on the ground, and the other three groups had no individuals doing so.

The introduced species perched on built objects most frequently of the six major groups, with less than 5% of individuals in each of the major native groups doing so. Honeyeaters perched on built objects more than any other major native group. In the less abundant groups, Tree Martins (swallows) were perched on built objects every time they were recorded.

Honeyeaters had the highest percentage of individuals foraging in native trees, followed by the thornbill group. The three other major native groups all exceeded the introduced group in percentage foraging in native trees, but had much lower percentages than the honeyeater and thornbill groups.

The rosella group and the introduced group perched most commonly in exotic trees, but all of the other major native bird groups did so as well to a lesser extent.

The introduced group perched on the ground most often of the major groups, with the rosella group being the most common major native group to do so. The corvid group and the honeyeater group perched on the ground in low numbers.

The thrush group foraged and perched on native shrubs most commonly, with all other major bird groups except the corvid group doing so in lesser numbers.

Honeyeaters foraged in exotic trees most commonly but only slightly more than the thornbill and introduced groups. The rosella group foraged in exotic trees in very small numbers.

Honeyeaters perched but introduced species foraged in exotic trees most commonly. Thornbills foraged in exotic shrubs in low numbers.

Introduced species had the highest percentage of individuals identified by sight, followed by the rosella group, the thrush group, the corvid group and the honeyeater group, all of which had greater than 50% of individuals identified by sight (Table 4.8). The thornbill group was the only major group with more than 50% (61%) identified by call. Of the less abundant groups, almost all bronzewings (90%) and 63% of swallows were identified by call, while all lapwings and birds of prey were identified by sight.

B.G	PE-N. TR	FO-GR	PE-B. OBJ.	FO-N. TR.	PE-E. TR.	PE-GR	FO-N. SH	PE-N. SH	FO-E. TREE	PE-E. SH	FO-E. SH	I.D.-SI	I.D.-SO
IG	1.75	**32.50**	**20.75**	0.88	9.38	**6.75**	0.00	0.13	1.63	1.00	**0.88**	**92.0**	8.0
TG	27.52	0.16	0.31	13.36	3.77	0.00	2.04	2.83	2.99	0.00	0.16	39.0	**61.0**
HG	26.79	0.60	4.76	**17.06**	5.36	0.20	2.78	1.19	**3.37**	**2.18**	0.79	54.0	46.0
RG	26.27	2.35	0.00	3.53	**9.41**	2.35	0.78	0.00	0.78	0.00	0.00	88.0	12.0
CG	30.58	7.02	2.48	4.13	5.79	1.65	0.00	0.00	0.00	0.00	0.00	56.0	44.0
TG	**46.73**	0.00	0.00	2.80	4.67	0.00	**6.54**	**6.54**	0.00	0.00	0.00	70.0	30.0
BG	0.00	0.00	0.00	0.00	0.00	4.76	0.00	0.00	0.00	0.00	0.00	10.0	90.0
LG	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.0	0.0
FG	83.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.0	0.0
SG	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	37.0	63.0
AV.	**24.30**	**14.26**	**12.83**	**4.18**	**3.84**	**1.57**	**1.21**	**1.07**	**0.88**	**0.32**	**0.18**	**64.6**	**35.4**

Table 4.8: Behaviours exhibited by the ten bird groups which are interactive with the habitat from most to least frequently exhibited (left to right). The six groups with over 100 individuals are colour-coded and the group for which the behaviour is most common is in bold, the four groups with low abundances are in pink. The last two columns indicate the percentage of each bird group that was identified by sight vs. sound. PE= perching, FO= foraging, N.= native, E.= exotic, TR.= tree, SH.= shrub, GR= ground, B. OBJ.= built object. IG= introduced group, TG= thornbill group, HG= honeyeater group, RG= rosella group, CG= corvid group,, TG= thrush group, BG= bronzewing group LG=lapwing group FG= falcon group and SG= swallow group, AV.=average percentage of total birds exhibiting behaviour.

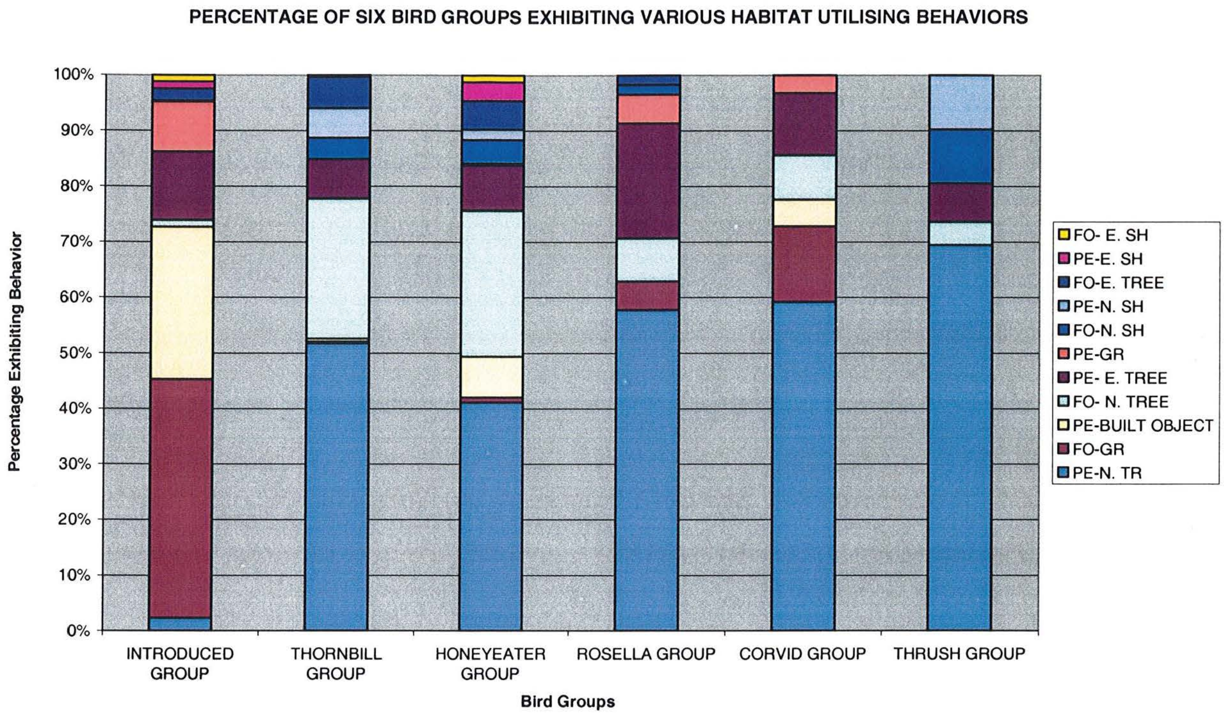


Figure 4.14: Percentage of bird groups exhibiting various behaviours. See Table 4.8 for abbreviations.

4.3.5 Bird Response to Season

With the exception of native altitudinal migrants, all bird types had more species which favoured summer in terms of abundance than those that were neutral or favoured autumn, but native summer migrants had the highest percentage favouring summer (Figure 4.15). Introduced non-migrants had the highest percentage of season neutral species followed by native summer migrants and native non-migrants. Native altitudinal migrants had the highest percentage favouring autumn followed by native summer migrants, native non-migrants and introduced non-migrants. Native altitudinal migrants had the highest percentage of species with too few individuals to include (one out of two) followed by native non-migrants and introduced non-migrants.

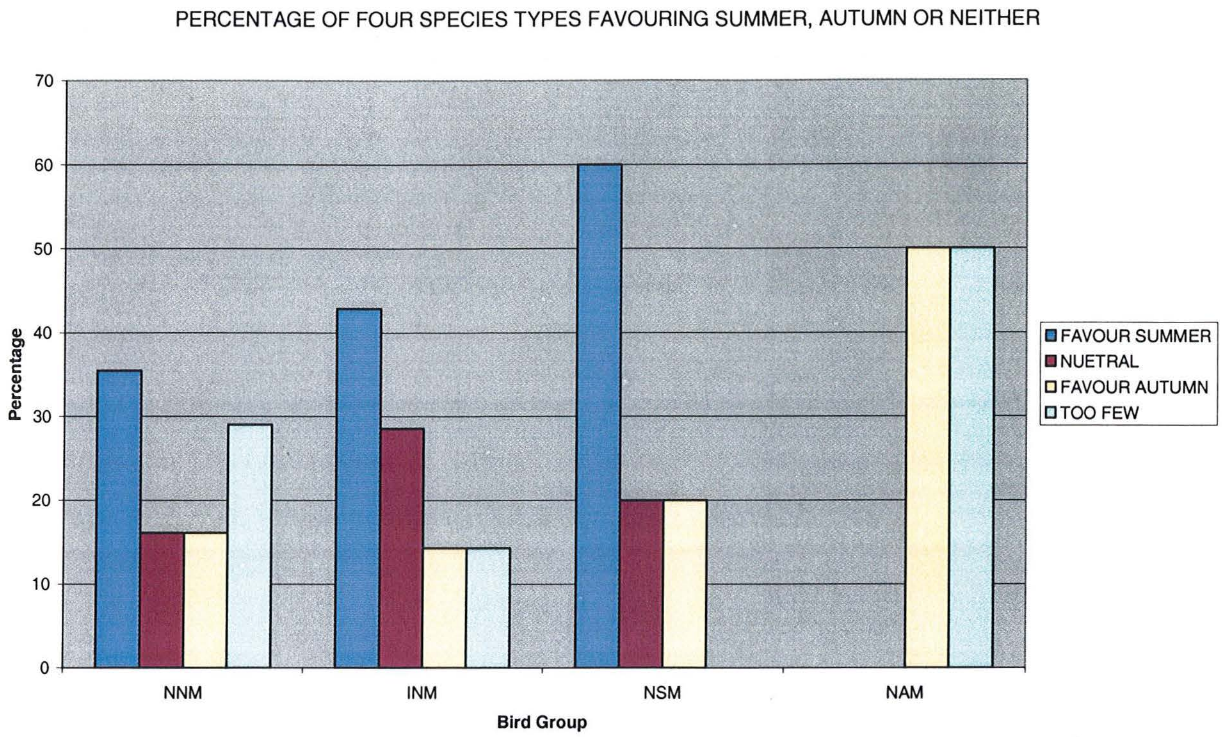


Figure 4.15: Percentage of four species types favouring summer, autumn, neither or having two few individuals to classify. NNM= native non-migrant, INM= introduced non-migrant, NSM= native summer migrant and NAM= native altitudinal migrant.

In all, 17 species favoured summer, 8 were neutral, 8 favoured autumn and 11 had too few individuals to classify (Table 4.9). Dusky Wood-swallows favoured summer by the highest margin as all individuals recorded were seen in the summer. New Holland Honeyeaters, Brush Bronzewings, Tree Martins and Tasmanian Scrubwrens also favoured summer strongly. Spotted Turtle-doves, Noisy Miners, Forest Ravens and Black-faced Cuckoo-shrikes favoured summer to a medium extent and House Sparrows, Sulphur-crested Cockatoos, Spotted Pardalotes, Laughing Kookaburras, Yellow Wattlebirds, Little Wattlebirds, Grey Shrike-thrushes and Grey Fantails favoured summer to a lesser extent. Australian Magpies, Scarlet Robins, Eastern Rosellas, European Blackbirds, Superb Fairywrens, Common Starlings, Silvereyes and Brown Thornbills were season neutral. Rock Doves, Black-headed Honeyeaters, Yellow-throated Honeyeaters and Musk Lorikeets favoured autumn weakly while Green Rosellas, Grey Currawongs, Striated Pardalotes and Eastern Spinebills favoured autumn strongly. Finally, Masked Lapwings, Grey Butcherbirds, Australian Hobbies, European Greenfinches, Strong-billed Honeyeaters, Olive Whistlers, Golden Whistlers, Tasmanian Thornbills, Yellow-tailed Black Cockatoos, Brown Falcons and Crescent Honeyeaters had too few individuals to classify.

SPECIES	PROP. DIF.	BIRD TYPE
DUWO	10	NSM
NHHO	4.33	NNM
BRBR	4.25	NNM
TRMA	4	NSM
TASC**	4	NNM
SPTU*	2.7	INM
NOMI	2.23	NNM
FOR A	2.13	NNM
BLCO	2	NSM
HOSP*	1.96	INM
SUCO	1.67	NNM
SPPA	1.52	NNM
LAKO*	1.5	INM
YEWA**	1.48	NNM
LIWA	1.41	NNM
GRSH	1.4	NNM
GRFA	1.3	NNM
AUMA	1.21	NNM
SCRO	1.17	NNM
EARO	1.03	NNM
EUBL*	1.02	INM
SUFA	0	NNM
COST*	1.22	INM
SIEY	1.24	NSM
BRTH	1.24	NNM
RODO*	1.26	INM
BLHO**	1.31	NNM
YEHO**	1.4	NNM
MULO	1.53	NNM
GRRO**	1.67	NNM
GRCU	1.71	NNM
STPA	1.95	NSM
EASP	11	NAM
MALA	NA	NNM
GRBU	NA	NNM
AUHO	NA	NNM
EUGR*	NA	INM
STHO**	NA	NNM
OLWH	NA	NNM
GOWH	NA	NNM
TATH**	NA	NNM
YEBL	NA	NNM
BRFA	NA	NNM
CRHO	NA	NAM

Table 4.9: Species by that which favours summer most strongly (top) to that which favours autumn most strongly (last one in blue) by the difference in proportion of individuals of a species seen in summer versus autumn (until SUFA) and autumn versus summer (after SUFA). Red= favours summer, black= season neutral, blue= favours autumn, green= too few individuals to classify. NNM= native non-migrant, INM= introduced non-migrant, NSM=native summer migrant, NAM= native altitudinal migrant. See Appendix II for guide to species codes.

Chapter 5 Discussion and Conclusion

5.1 Variation in bird diversity, abundance and species composition across the urban gradient

5.1.1 Species richness

As with other urban bird studies (Beissinger and Osborne, 1982; Jokimaki and Suhonen, 1993), species richness decreased with increasing urbanization, being lowest at the city centre and highest at the least developed native bushland reserve (Knocklofty). The species accumulation charts reinforce this trend, as Knocklofty and to a lesser extent the other bushland remnants accumulated species at a faster rate than the urban sites, and still appeared to be accumulating species to some extent when the study period came to an end. This was particularly true in the case of native species, which were highest in species richness at the bushland sites, intermediate in a residential area and very much lower in the commercial city centre. In contrast, the case of introduced species was just the opposite, as there were more introduced species in the more urban sites than the native vegetation sites. This finding is also consistent with other studies (Clergeau *et al.*, 1998; Germaine *et al.*, 1998).

As is the case with other islands (MacArthur and Wilson, 1967), Tasmania has a high prevalence of endemic species. In the case of native birds, it has 12 endemic species and 26 endemic subspecies (Thomas, 1972). As Tasmania is the only place they occur, conservation of endemic species merits special consideration and was therefore included in this study. Like other native species, endemic species were more common in the native vegetation remnants than in the urban sites and were entirely absent from the city centre. The other studies do not mention the prevalence of endemic species, but the findings of this study in relation to endemic species are consistent with a more species rich bird community in the least urbanized sites.

5.1.2 Abundance

Total abundance trends by site were mixed. The two most urban sites, Hobart and Sandy Bay, had higher averages abundances than two native remnant sites, the

Queen's Domain and Bicentennial Park. This is consistent with the findings of Beissinger and Osborne (1982) who found that abundance was higher in more urbanized sites. However, Knocklofty Reserve had the highest average abundance of all, indicating that relative abundance of urban versus natural sites may depend on the habitat quality of the natural site. Another possibility is that Knocklofty Reserve is an anomaly, given that the timeframe of this study allowed for few replications of sites.

However, when only the abundance of native species is considered, average abundance is higher for all three native remnant sites than the two urban sites, and it is higher in the residential (Sandy Bay) than the commercial site (Hobart). Thus, the high average abundances in the urban sites most likely result from an increased prevalence of individuals of exotic species. This is consistent with the findings of many urban bird studies (Jones, 1981; Green, 1986; Catterall *et al.*, 1989; Clergeau *et al.*, 1989) which indicate that urban settings are dominated by the superabundance of a few introduced species. Indeed, four of the five most abundant species in this study were introduced.

Note that the abundance of one Tasmanian endemic species, the Tasmanian Thornbill, was probably under-estimated as it was often grouped together with Brown Thornbills.

5.1.3 Species composition and site correlations

Just as Wood (1996) found, there were few generalist species in this study, and the majority of habitat specialists were woodland specialists (29 species). This is consistent with the observation that woodland habitats were more species rich than urban habitats. Although fourteen species were habitat generalists of some kind, only two showed no habitat preference at all, while eight showed some preference for woodland habitats and four for urban habitats. Also, five of the seven urban specialists were introduced, reinforcing the notion that exotic species are favoured in more urbanized areas.

As was found in other urban bird studies, dietary habit and mobility were influential in determining habitat specialization. Like White *et al.* (2005), this study found that insectivores and nectarivores declined in the urban habitats compared to the woodland habitats. All the woodland specialists in this study are insectivores or nectarivores except the two falcon species, which are carnivores and the Brush Bronzewing which is a granivore. More generalist and urban specialist species than woodland specialist species were granivores or omnivores, just as in other studies (see Chapter 2 - Background). The urban specialists and generalists which are insectivores were generally ground foragers, as opposed to woodland specialists that largely foraged in trees or shrubs. Also, only one urban specialist and one generalist was a summer migrant, which is consistent with the notion that urban bird species are mostly sedentary (Jokimaki *et al.*, 1996). Furthermore, the urban specialist which was a summer migrant (the Tree Martin) was only seen twice overall, so it is possible that it was not actually an urban specialist, but just happened to be seen in urban habitats on those two occasions.

Habitat associations by bird assemblage were largely as one would expect, but there were a couple of anomalies. Not surprisingly, the bird assemblages of all the urban habitats were closely associated with one another and those of the woodland habitats were also closely associated with one another, but urban and woodland bird assemblages were quite different from each other. However, the Queen's Domain grassland habitat and exotic vegetation habitat were not associated with either the other woodland or urban habitats. The grassland habitat was most likely different from other woodland habitats largely due to the presence of the Noisy Miner, which has been shown to exclude other woodland specialist species, especially smaller birds (Grey *et al.*, 1998; MacDonald and Kirkpatrick, 2003). Presence of the Noisy Miner has been associated with more open, disturbed habitats (Grey *et al.*, 1998) such as the Queen's Domain grassland, which has less dense vegetation than the other woodland habitats, has more pedestrian and dog traffic and is adjacent to lawn covered sporting grounds.

However, the presence of the Noisy Miner does not explain why the Queen's Domain exotic habitats were not correlated with other urban habitats such as urban parks. This is most likely due to the adjacency of the exotic sites to the native vegetation sites of the Queen's Domain, which results in a spill over of species present in the native habitats into the exotic ones. This is supported by the findings of Chamberlain *et al.* (2007), who found that urban parks were more species rich when surrounded by residential gardens than when surrounded by buildings. Another factor is that the botanical garden, which is one of the exotic vegetation sites in the Queen's Domain, is so much larger and more diverse in vegetation than all the other urban parks, therefore it exerts a dominant influence on the bird communities in the exotic habitats of the Queen's Domain. Studies have shown size (Jokimaki, 1999; Fernandez-Juricic, 2000b) and habitat heterogeneity (Freemark and Merriam, 1986; Bellamy *et al.*, 1996) to be important determinants of bird communities in urban parks. Most likely adjacency and the botanical garden are both influential factors in explaining the difference between exotic vegetation habitats in the Queen's Domain and those in the other urban habitats.

5.2 Conservation value of urban parks and native remnant patches

Native vegetation remnants had significantly higher average native species richness than urban habitats, which echoes the findings of other urban bird studies (Wood, 1996 and LeFort, 2002). In addition, 20 native species (47.62%) were found only in the native vegetation remnants and not in urban habitats at all. Another 15 native species (35.7%) were only found outside of the native vegetation remnants (in urban areas) in very low abundances. Of the 42 native species found, only 7 species (16.67%) were relatively common in the urban habitats outside of the native vegetation remnants. Therefore, without the native vegetation remnants, almost half the native species would almost certainly be lost altogether, and possibly significantly more than that as many of the other native species may not have been able to sustain themselves on the urban habitats alone. It is therefore very important to maintain native vegetation remnants in the urban matrix in order to maintain a high diversity of native species.

As all three native vegetation patches in this study were over 100 ha and comparable in size to one another, size was not assessable as an important factor in determining species richness in the native remnant patches. Instead, habitat quality may best explain the observed differences between the remnant patches. This will be elaborated on in the following section. Nevertheless, size is clearly an important factor to explain the difference in species richness between native vegetation remnants and urban parks, the former being many times larger than the latter.

Although urban parks alone are clearly not enough to sustain a high native species diversity given the results, they still harbour more native species on average than the surrounding streetscapes. This finding reflects similar findings of other studies (Fernandez-Juricic and Jokimaki, 2001). Thus, they may still have value as a supplement to the less disturbed native vegetation remnants in several ways. First of all, they may help to increase connectivity in the landscape, thereby facilitating avian movement, by acting as stopover points and corridors between native remnant patches (Fischer and Lindenmayer, 2001). Secondly, ornamental plants in urban parks and gardens may act as a supplementary food source for native birds, especially during winter when fewer native plants are in flower (Donato, 1989; Clergeau *et al.*, 1998).

Thirdly, in autumn passing migrants may use urban parks as a stopover point en route to the mainland. Thus, although alone they cannot sustain viable populations of many native bird species, urban parks do have habitat value to native birds when compared to the surrounding urban streetscape.

Just as with other studies (e.g. Chamberlain *et al.*, 2007), the surrounding streetscape played a role in determining native bird species richness in urban parks. For example, although urban parks were more species rich than surrounding streets in both the city centre (Hobart) and in the residential area (Sandy Bay), Sandy Bay parks were more species rich than Hobart parks. In fact, Sandy Bay streets were more species rich than Hobart parks. This is likely because of the presence of gardens in residential areas, which have been shown to increase species richness in parks (Chamberlain *et al.*, 2007). Thus, although urban parks attract relatively more bird species than urban streets, the absolute number is dependent on surrounding habitat factors. This is probably largely due to the small size of most urban parks, as Fernandez-Juricic (2000b) found that surrounding habitat had a greater influence in determining bird communities of smaller parks.

Unlike Hobart and Sandy Bay, the urban parks (exotic habitats) in the Queen's Domain were less species rich than the surrounding landscape. However, the surrounding landscape in the Queen's Domain is largely native vegetation rather than the built environments of the other two urban sites. This finding reinforces the notion that while urban parks have some value for conserving native birds, they are secondary to larger, native vegetation patches. Also, many of the bird species found in the Queen's Domain urban parks, specifically the botanical garden, were found in autumn on the last survey, implying again that the urban parks may be more utilized by native birds during the cold months as a supplementary food source or stopover point.

5.3 Bird-habitat quality relationships

5.3.1 Birds and plants

Plant species richness and composition varied across the broad habitat types. Not surprisingly the woodland habitats were more similar to each other than to the urban habitats and vice versa. The urban habitats had more plant species than the woodland habitats, but the woodland habitats had more native plant species. The urban habitats were also more varied in plant species composition than the woodland habitats as they incorporated a range of garden plants. Gardens contain a wide variety of exotic plants from around the world, where as the woodland habitats were limited by the number of species found locally, and were therefore less diverse and more similar to one another. Mainland natives were also more common in the urban than the woodland habitats, perhaps planted in an attempt to attract birds or butterflies.

Just as in other studies (Catterall *et al.*, 1989; Green *et al.*, 1989; Daniels and Kirkpatrick, 2006), there was a strong positive correlation between native plants and native birds and a negative correlation between introduced plants and native birds. This relationship was strongest for native birds as a whole, the thornbill group and the honeyeater group but was weaker for the other native bird groups. For the corvid group this was probably due to the cosmopolitan nature of the Forest Raven, the most widespread and abundant species in that group. In the case of the thrush group, it may have been because this group was the least abundant and because fairywrens and robins were sometimes found in the botanical garden. The rosella group had the lowest correlation with native plants probably because rosellas and sometimes Sulphur-crested Cockatoos were common in urban parks.

Native bird correlations with mainland native plants generally were not strong and were mixed. Native species as a whole, the thornbill group, the corvid group and the thrush group had negative correlations with mainland native plants, implying that they were not a good substitute for Tasmanian native plants for native birds. However, the honeyeater and rosella groups had positive correlations with mainland native plants. All of these birds are at least partially nectarivores, implying that Australian mainland native plants may be most beneficial for nectarivorous species.

Exotic birds had the opposite reaction, being negatively correlated with native plants and positively correlated with exotic and mainland native plants. This is consistent with the results of other studies (Green, 1986; Mills *et al.*, 1989) and may help explain why urban environments favour exotic bird species.

All bird groups had statistically significant positive correlations with increasing vegetation cover except for the rosella group. Native species as a whole, exotic species, honeyeaters and the thornbill group were also significantly positively correlated with vegetation cover in the ground, under-storey and middle storey layers. Many other studies have found a positive relationship between vegetation cover and birds as well (Beissinger and Osborne, 1982; Munyenyembe *et al.*, 1989; Fernandez-Juricic, 2000b). However, the corvid group was only positively correlated to the ground vegetation cover (and to total percent cover), probably because most the species in this group (such as the Forest Raven, Grey Currawong and Australian Magpie) spend more time foraging on the ground than the other groups. The thrush group was positively correlated with the middle and ground vegetation cover but not the under-storey, probably because fairywrens tend to forage on the ground and all the other species in this group spend most of their time in the trees, rather than at shrub level. The rosella group was not correlated with vegetation cover probably because these species favoured more open habitat types in this study such as the Queen's Domain grassland and urban parks. The lack of correlations with the over-storey vegetation cover are probably due to the fact that few count points had vegetation in that height class, rather than a true lack of relationship to birds. Also, most the bird groups had significant positive correlations with leaf and dead wood litter cover, likely because it provides cover for smaller ground dwelling birds and harbours more invertebrates which provide a good food source. Finally, positive correlations with bare soil probably stem more from the implication that sites with more exposed soil are not paved environments than the exposed soil per se.

Correlations with vegetation complexity were mixed. All native bird groups had positive correlations with number of vegetation layers, and this relationship was significant for all native birds, honeyeaters and the thornbill group. This finding is consistent with those of other studies (Gavereski, 1976; Beissinger and Osborne, 1982; Luniak, 1983). Exotic species on the other hand, had negative correlations with number of vegetation layers, probably because they were most common in urban areas were vegetation complexity is at its lowest.

5.3.2 Birds and invertebrates

On the whole, urban sites did not appear to be significantly different in invertebrate abundance and species richness than native woodland sites. As there were only four introduced species, two of which were found at native as well as urban sites, the similarity in species richness between urban and native sites cannot be explained by the prevalence of exotic species in the urban sites. However, exotic species, particularly Argentine ants did make up a significant portion of the total abundance in the urban sites, particularly at Sandy Bay. Therefore without Argentine ants, the native sites may have had larger abundances of invertebrates than the urban sites, at least in the case of

Sandy Bay. However, overall the results of this study support those of Alaruikka *et al.* (2002) who also found no difference in species richness and abundance of invertebrates in native versus urban sites.

In this study, variation in species richness and abundance seemed to be greater within sites than between sites, as the two Knocklofty Reserve, Queen's Domain and Sandy Bay locations were significantly different from each other in both species richness and abundance. This could be because microclimatic differences within a site are more important to smaller animals such as invertebrates than to larger animals such as birds or mammals (McQuillan, 2007, pers. com.).

Microclimatic differences may also explain large variations in invertebrate species composition sometimes even between different trees at the same sampling location. The species of the tree or shrub appeared to play a role in its invertebrate species composition. However, some urban trees and shrubs appeared to be related to some native trees and shrubs in invertebrate species composition. These may have been associated partially just by all having low species richness and abundance rather than similar species compositions (McQuillan, 2007, pers. com.). In addition, the size and age of the tree or shrub sampled may have been determining factors in invertebrate species composition, and variation in these may explain variations on trees and shrubs which are adjacent to each other. Also, adjacent trees and shrubs which were associated may have been so because of one particular aspect of their species composition. For example, Sandy Bay trees and shrubs may have been associated largely by the presence of the Argentine ant rather than by similarities in native species assemblages.

Differences in invertebrate species richness and abundance between urban and native sites cannot solely explain variation in bird diversity and abundance along those lines from the results of this study. Likewise, they cannot explain the native bird preference for native plants, which is in direct contrast to the findings of Green (1986) and Bhullar and Majer (2000). However, few replications, especially in the urban habitats, may have biased the results of this study and masked any pattern which may have existed. This study was also limited in that it only sampled invertebrates on trees and shrubs, while invertebrates found on the ground and in the air may also be important for some bird species. Also, ground dwelling invertebrates may have a higher prevalence of introduced species in urban areas (McQuillan, 2007, pers. com.), which may be positively correlated with introduced birds which forage primarily on the ground (Green, 1986).

Although differences in invertebrate abundance and species richness did not appear to play a role in determining bird diversity and abundance, differences in invertebrate species compositions may have been important to birds. For example, introduced species such as Argentine ants may not appeal to native birds as much as other invertebrates such as spiders, which are more common in native habitats than urban ones (MacIntyre *et al.*, 2001; Rango, 2005). However, the results of this study are not sufficient to support this hypothesis, which will have to be tested in a future study.

Finally, seasonal variation in invertebrate abundance may have important implications for birds in both urban and natural studies, but again, are beyond the scope of this study which only sampled invertebrates once in late summer, 2007.

5.3.3 Birds and human disturbance

The finding that all native species groups except the rosella group were negatively correlated to all human disturbance variables is consistent with other studies which found negative relationships between native birds and built environments (White *et al.*, 2005), pedestrian traffic (Gutzwiller *et al.*, 1998; Fernandez -Juricic, 2000a), vehicle traffic and noise level (Reijinen and Foppen, 1995). Given the results of this and other urban bird studies, these four human disturbance variables play an important role in explaining why native birds are less species rich and abundant in urban than in natural settings. Although cockatoos, lorikeets and rosellas seem to be less sensitive to human disturbance than other native species, as they are only negatively correlated with the built environment of the four human disturbance variables. This is possibly because they are usually found in large flocks, as Gutzwiller *et al.*, (1998) found that birds were less sensitive to the presence of humans in the presence of conspecifics.

Introduced bird species were positively correlated with all human disturbance variables which is consistent with the findings of White *et al.* (2005), who found that anthropogenic features such as buildings favoured exotic species. Also, Cooke (1980) found that birds were less sensitive to approaching pedestrians in urban than in rural settings, perhaps as a consequence of becoming habituated to human presence. Some bird species and individuals may even have come to rely on human hand outs or left-overs as a food supply. In this study introduced House Sparrows and Rock Doves in particular were observed eating left-over human food on several occasions.

5.3.4 Bird use of habitat features

Bird use of habitat features is directly related to the correlations with habitat features found in previous sections. For example, just as other studies have found (Green, 1989), this study found that exotic species foraged and perched on the ground more often than any of the native species groups. Exotic species also perched on built objects more often than native species groups, which is also supported by the results of other urban bird studies (Green, 1986; Green *et al.*, 1989). This finding is also supported by other findings in this study, which suggest that exotic species are more favoured by urban habitat features than native species.

All the native species groups perched and foraged in native trees more often than exotic species did, which supports the positive correlation between native birds and native plants found in this study. Perching in a native tree was also the most common habitat utilizing behaviour exhibited by birds in all the native species groups. However, it is worth mentioning that this trend is could be partially caused by a greater availability of native perch options in native habitats, where most native bird species were found. With the exception of the corvid and rosella groups, which utilised native shrubs very little and exotic shrubs not at all, native species also more commonly foraged and perched in native shrubs than exotic species did.

Use of exotic vegetation was mixed between native and exotic species. The rosella group perched in exotic trees most often, followed closely by exotic species. This is probably due to the prevalence of rosellas and Sulphur-crested Cockatoos at urban parks, and the presence of introduced pines in the Queen's Domain grassland habitat, which Eastern Rosellas were frequently observed to perch in. The cockatoos and rosellas may be obtaining s supplementary food source from flowering and fruiting exotic plants, as they are primarily frugivores (although they may also eat some insects on an opportunistic basis). This is supported by the fact that this bird group is less positively correlated with native plants and less negatively correlated with exotic plants than the other native bird groups. The honeyeaters observed in exotic habitats may be obtaining nectar from exotic flowering plants as supplementary food source, as they were most frequently seen group foraging on exotic trees and perched in exotic shrubs and the second most frequently seen group (after exotic species) foraging on exotic shrubs. Therefore the negative correlation between exotic plants and honeyeaters may be partly due to the fact that most exotic plants are found in areas with high human disturbance rates than a disinclination to use exotic plants. Also, some honeyeater species were more inclined to use exotic plants than others, particularly New Holland Honeyeaters, Little Wattlebirds, Yellow Wattlebirds and Crescent Honeyeaters.

These results imply that while introduced bird species clearly utilise exotic plants, at least two of the native species groups also use exotic plants as a supplementary food source. This is consistent with the results of Donato (1989) and Daniels (2005) who found that native birds used exotic garden plants as a food source to some degree, especially in the winter. In this study, nectarivorous and frugivorous species used exotic plants more than the insectivorous and carnivorous native birds, implying that the primary food source is the fruit and flowers of the exotic plant itself and not any invertebrate resources found on it.

5.3.5 Birds and season

The finding that more species favoured summer in three main species types, including native non-migrants, introduced non-migrants, native summer migrants, is probably a reflection of greater resources available in this season. More native plants are flowering, fruiting and seeding at this time of year and invertebrates are more abundant as well (Bolger *et al.*, 2000; Rango, 2005). In addition, the longer day length and higher average temperatures may also favour bird species.

Likewise, the finding that introduced non-migrants have the highest proportion of season neutral species of all four species types probably reflects their greater reliance on anthropogenic food sources which are more likely to be available year round, such as garden plants, bird feeders and human left-overs.

With the exception of native altitudinal migrants, all the species types had few species that favoured autumn. This results from the fact that this study only incorporated altitudes under 400m, and therefore does not necessarily reflect a lower abundance of these species in summer, but rather that they were still at higher altitudes than those surveyed in this study. Also, there are few species of this type (two) which makes it difficult to establish a pattern.

Although the highest proportion of native summer migrants favoured summer, as would be expected, one species (the Silvereye) was season neutral and one (the Striated Pardalote) favoured autumn. In the case of the Silvereye, this result was likely due to the fact that some individuals of this species have been known to over-winter in

Tasmania (Daniels, 2005). They may also rely more heavily on the urban vegetation of gardens and parks in the winter, rendering them more conspicuous as urban environments have less vegetation cover. Daniels (2005) found that Silvereyes occurred less frequently but were more abundant in gardens in the winter than in the spring. This finding may also result from the fact that Silvereyes form large feeding flocks in the autumn and winter, and so may be observed less frequently but in high abundance in these seasons (Brereton, 2007, pers. comm.) In the case of the Striated Pardalote, it is possible that many individuals simply had not migrated yet, as the survey ended in April, or perhaps they were more conspicuous as they moved through the landscape on their migration route.

5.4 Study constraints and biases

As with any study, there were a number of potential biases and constraints associated with this study. First of all, there was a difference in detectability between the more open habitat types such as the urban sites and Queen's Domain grassland and the more densely vegetated habitat types such as the Bicentennial Park wet sclerophyll forest in particular. This likely resulted in an under-estimation of species richness and abundance in this habitat type. Likewise, it resulted in a higher number of birds identified by call rather than sight. Smaller birds were also identified by call more often than larger birds. Birds identified by call could not be included in the behavioural portion of the study, and thus small birds and those in dense habitats are under represented in that part of the study. Any observer biases were consistent across the sites and survey dates because there was only one bird observer, resulting in consistent results relative to each other. In terms of vegetation, plants in people's yards were not included by species in order to avoid trespassing and therefore plant species richness in residential sites was probably under estimated. In the case of invertebrates, biases may have resulted because there was not equal effort at each site (Hobart had only one sampling location), only invertebrates on plants were surveyed and so ground dwelling invertebrates were not accounted for and there were three different observers who may have inadvertently done their surveys slightly differently from one another.

In addition, this study was constrained by time and budget limitations, as all studies are. As a result, not all bird species were detected at any one site (except perhaps Hobart). For example, in Bicentennial Park, neighbours and local bush care group members have recorded 56 diurnal species, over approximately 50 years (Hird, 1994), while this study only recorded 25 species. Although many of the species they recorded haven't been seen for decades or are seen only rarely, it still goes to show that many more species are present than those detected in this study. However, as equal effort was used in bird surveys at each site, the data collected in this study still serves as a useful comparison between sites. In the case of plants and invertebrates, the under-estimation of species richness is even greater as the total number of species is greater, but again still serves as a useful comparison between sites. For example, McQuillan (1998) found 380 species of invertebrates in Bicentennial Park alone and concedes that this is only a portion of species actually present. Observation of seasonal variation was also biased by the short term nature of this study, which only accounted for nine weeks of a 52 week year (only 17.3%) and therefore could not incorporate the full scale of seasonal variation. Nevertheless, trends such as the tendency for most species to favour summer are still valuable observations in the quest to improve understanding of urban bird ecology. Finally, time constraints limit the number of replications of sites in this study to five and the number of repetitions of bird surveys to six per site.

5.5 Recommendations for future studies

This study could be enhanced by extending the number of replications and the timeframe and expanding exploration of the bird habitat relationship. More replications of sites within Hobart, such as the inclusion of more suburbs and native vegetation reserves would help to confirm patterns found in the various habitat types in this study. Likewise, comparing Hobart urban birds to urban birds in other cities of comparable size and climate would further confirm patterns and highlight variations between comparable cities.

Alternatively, extending the timeframe of the study over a full year, several years or even decades could aid in monitoring changes in urban birds throughout seasons and over time. Most urban bird studies (including this one) are conducted over a relatively short time period such as one season, and do not incorporate annual or even seasonal variation in urban bird communities. Therefore long term patterns in urban bird community dynamics such as colonizations and extinctions of species are poorly understood. A long term study could help to rectify this.

In terms of bird habitat relationships, bird-plant relationships in an urban setting have been relatively well studied (Catterall *et al.*, 1989; Green *et al.*, 1989; Daniels and Kirkpatrick, 2007) compared to urban bird relationships to invertebrates and human disturbance. More replications of concurrent bird and invertebrate surveys in urban areas, incorporating invertebrates on plants and on the ground, can help to examine this relationship further. Most urban bird studies have focused on built environment as a measure of human disturbance (White *et al.*, 2000). Further studies of the effect of vehicle and pedestrian traffic and human caused noise can help to determine the influence of these factors on bird communities. Finally, in future studies, the incorporation of other habitat variables such as the presence of water, pets and feral animals and age of suburb, among others, can help complete the picture of bird-habitat relationships in an urban setting.

5.6 Conclusion

From the results of this study, I conclude that the maintenance of native vegetative patches in the urban landscape is essential for the maintenance of a high native bird diversity and abundance in urban areas. This stems from the fact that the majority of native birds (86% in this study) show at least some preference for native woodland habitats over urban habitats, and it is likely they would not be sustained without such habitats. This is particularly true for Tasmanian endemic bird species, which were not observed at all in the Hobart city centre and only rarely in residential areas. In addition, results from this and other similar studies suggest that native vegetation patches effectively exclude introduced birds most effectively of all habitats in the urban matrix. However, this and other studies suggest it may also be necessary to exclude or remove Noisy Miners from remnant patches for the conservation of small woodland birds in some cases (Grey *et al.*, 1998). Large vegetation remnants with a high native plant species richness, percent cover and complexity are particularly favourable to native birds and detrimental to both exotic birds and Noisy Miners, which are edge specialists.

Nevertheless, urban parks and gardens can provide connectivity in the landscape and provide supplementary resources for native birds, especially during winter. Just as for native remnant patches, large urban parks and gardens with primarily native plants and a high vegetation cover and complexity are particularly beneficial to native birds.

Connectivity of parks, gardens and native vegetation remnants throughout the urban matrix can also increase native bird diversity.

Variation in vegetation and human disturbance appeared to be more important determinants of native bird diversity and abundance in Hobart than did invertebrate variation. Therefore the presence of native vegetation and vegetation cover and complexity should be maximized in urban areas, which may also increase the abundance of invertebrates. Built structures, pedestrian traffic, vehicle traffic and human noise levels should be kept to minimum wherever possible, such as in native vegetation remnants or large urban parks. For example, established walking trails and dog leash laws can minimize the area of the remnant or urban park which is disturbed by humans. Paved areas should also be kept to a minimum in these areas. Where minimization of human disturbance is impossible, such as on urban streets, the planting of street trees and gardens can provide birds with some refuge from the traffic and noise. Further studies are needed to determine more management actions, particularly in relation to invertebrates.

The results of this study, supplemented by those of other studies, infer that both habitat quality and quantity are important to native birds. That is that large, well connected native vegetation patches, urban parks and gardens with high native plant diversity, vegetation cover and complexity and low amounts of human disturbance are needed to conserve native birds in an urban setting. Awareness of which aspects of habitat quality and quantity are most important to native birds, as found in this and other urban bird studies, can lead to a future in which humans and birds, and other native wildlife as well, can co-exist and thrive in an increasingly urbanized world.

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APPENDIX I: BIRD DATA SHEETS 2007

Date:	Site:

Weather Conditions (temperature/percent cloud cover/fine (F), rain (R), wind (W)

Point	Time[1]	Species	#	Location[2]	Behaviour[3]	Plumage[4]	ID[5]

Notes:

[1] Start time/end time for survey period of point

[2] Distance from point/ left (L), right (R), front (F) or back (B) of point/height (ground (GR), shrub (SH), tree (TR) or air (AI))/type of vegetation or built object seen on or not applicable (NA)

[3] perched (PE), singing (SI), flying (FL), foraging (FO), courtship behaviour (CB), feeding young (FY), begging parent (BP), begging humans (BH), chasing (CH), fleeing (FL), fighting (FI)

[4] Age (adult (AD) or juvenile (JUV)) sex (male (M) or female (F))- UK if any of these are unknown, NA if plumage variation not applicable to the species

[5] Identified by sight (SI) or song (SO)

Incidental Bird Sightings

Date/Time	Weather[6]	Site	Species	#	Location[7]	Behaviour[8]	Plumage[9]	ID[10]

Point Key: Points are labelled by site, environment type and number

[6] Temperature/percent cloud cover/ fine (F), rain (R) or wind (W)
[7] Point closest to/land marks or street name/height (ground (GR), shrub (SH), tree (TR) or air (AI))/vegetation or built object found on
[8] perched (PE), singing (SI), flying (FL), foraging (FO), courtship behaviour (CB), feeding young (FY), begging parent (BP), begging humans (BH), chasing (CH), fleeing (FL), fighting (FI)
[9] Age (adult (AD) or juvenile (JUV))/sex (male (M) or female (F)- UK if any of these are unknown. NA if plumage variation not applicable to the species
[10] Identification by sight (SI) or song (SO)

Point Descriptions

Site:	Point:
Slope:	GPS Coordinates:

Description of Location:
Photo Numbers:

Dominant Plant Species or Man Made Features and Percent Cover:

Over-storey:
Middle-storey:
Under-storey:
Ground Level:
Weeds:

Surface Type (Soil Type or Pavement):

Site:	Point:
Slope:	GPS Coordinates:

Description of Location:
Photo Numbers:

Dominant Plant Species or Man Made Features and Percent Cover:

Over-storey:
Middle-storey:
Under-storey:
Ground Level:
Weeds:

Surface Type (Soil Type or Pavement):

APPENDIX II: SPECIES CODES (first two letters of each word in the common name, *= introduced, **= Tasmanian endemic):

Family: FALCONIDAE
AUHO= Australian Hobby, *Falco longipennis*
BRFA= Brown Falcon, *Falco berigora*

Family: CHARADRIIDAE
MALA= Masked Lapwing, *Vanellus miles*

Family: COLUMBIDAE
SPTU*= Spotted Turtle-dove, *Streptopelia chinensis*
RODO*= Rock Dove, *Columba livia*
BRBR= Brush Bronzewing, *Phaps elegans*

Family: CACATUIDAE
SUCO= Sulphur-crested Cockatoo, *Cacatua galerita*
YEBC= Yellow-tailed Black Cockatoo, *Calyptorhyncus funereus*

Family: LORIIDAE
MULO= Musk Lorikeet, *Glossopsitta concinna*
RALO= Rainbow Lorikeet, *Trichoglossus haematodus*

Family: PLATYCERIDAE
EARO = Eastern Rosella, *Platycerus eximus*
GRRO**= Green Rosella, *Playcercus caledonicus*

Family: CUCULIDAE
FACO= Fan-tailed Cuckoo, *Cacomantis flabelliformis*

Family: ALCEDINIDAE
LAKO*= Laughing Kookaburra, *Dacelo novaeguineae*

Family: HIRUNDINIDAE
WESW= Welcome Swallow, *Hirundo neoxena*
TRMA= Tree Martin, *Hirundo nigricans*

Family: CAMPEPHAGIDAE
BLCO= Black-faced Cuckoo-shrike, *Coracina novaehollandiae*

Family: MUSCICAPIDAE
EUBL*= European Blackbird, *Turdus merula*
GOWH= Golden Whistler, *Pachycephala pectorales*
GRFA= Grey Fantail, *Rhipidura fuliginosa*
GRSH= Grey Shrike-thrush, *Colluricincla harmonica*
OLWH= Olive Whistler, *Pachycephala olivacea*
SCRO= Scarlet Robin, *Petroica multicolour*
DURO**= Dusky Robin, *Melanodryas vittata*

Family: MALURIDAE
SUFA= Superb Fairy-wren, *Malurus cyaneus*

Family: ACANTHIZIDAE
TASC**= Tasmanian Scrubwren, *Sericornus humilis*
BRTH= Brown Thornbill, *Acanthiza pusilla*
TATH**= Tasmanian Thornbill, *Acanthiza ewingii*

Family: MELIPHAGIDAE
YEWA**= Yellow Wattlebird, *Anthochaera paradoxa*
LIWA= Little Wattlebird, *Anthochaera chrysoptera*
NOMI= Noisy Miner, *Manorina melanocephala*
YEHO**= Yellow-throated Honeyeater, *Lichenostomus flavicollis*
NHHO= New Holland Honeyeater, *Phylidonyris novaehollaniae*
BLHO**= Black-headed Honeyeater, *Melithreptus affinis*
STHO**= Strong-billed Honeyeater, *Melithreptus validirostris*
EASP= Eastern Spinebill, *Acanthorhynchus tenuirostris*
CRHO= Crescent Honeyeater, *Phylidonyris pyrrhoptera*

Family: PARDALOTIDAE
SPPA= Spotted Pardalote, *Pardalotus punctatus*
STPA= Striated Pardalote, *Pardalotus striatus*

Family: ZOSTEROPIDAE
SIEY= Silvereye, *Zostecops lateralis*

Family: PLOCEIDAE
BEFI= Beautiful Firetail, *Stagnopteula bella*

Family: ARTAMIDAE
DUWO= Dusky Woodswallow, *Artamus cyanopterus*

Family: CRACTICIDAE
AUMA= Australian Magpie, *Gymnorhina tibecen*
GRBU= Grey Butcherbird, *Cracticus torquatus*
GRCU= Grey Currawong, *Strepera versicolor*

Family: CORVIDAE
FOR A= Forest Raven, *Corvus tasmanicus*

Family: PASSERIDAE
HOSP*= House Sparrow, *Passer domesticus*

Family: FRINGILLIDAE
EUGO*= European Goldfinch, *Carduelis carduelis*
EUGR*= European Greenfinch, *Carduelis chloris*

Family: STURNIDAE
COST*= Common Starling, *Sturnus vulgaris*

APPENDIX III: TOTAL AND AVERAGE ABUNDANCE BY SITE

TOTAL ABUNDANCE BY SITE						
SPECIES	KR	BP	QD	SB	HO	TOTAL
BRTH	**173**	119	29	0	0	**321**
RODO*	0	0	31	0	**214**	**245**
HOSP*	0	0	0	**124**	117	**241**
EUBL*	1	11	17	**90**	46	**165**
FOR A	**68**	31	39	9	11	**158**
COST*	0	0	9	**94**	54	**157**
YEHO**	**81**	50	10	0	0	**141**
SPPA	**94**	27	11	0	0	**132**
SIEY	13	26	0	**77**	3	**119**
MULO	0	0	**109**	0	0	**109**
LIWA	0	13	13	**58**	8	**92**
YEWA**	**29**	21	23	8	0	**81**
EARO	0	0	**65**	7	3	**75**
NOMI	0	0	**67**	0	0	**67**
BLHO**	**45**	6	3	0	0	**54**
AUMA	3	0	**47**	1	0	**51**
STPA	**25**	4	16	0	0	**45**
SPTU*	0	0	0	11	**25**	**36**
GRFA	**17**	12	4	1	0	**34**
NHHO	2	6	0	**25**	0	**33**
SUCO	0	9	1	**15**	0	**25**
GRCU	**14**	5	2	0	0	**21**
BRBR	0	**20**	0	0	0	**20**
GRRO**	**11**	4	0	5	0	**20**
EUGL*	0	6	**8**	2	0	**16**
SUFA	**8**	3	2	0	0	**13**
LAKO*	**7**	2	1	1	0	**11**
GRSH	**7**	4	0	0	0	**11**
EASP	**7**	4	0	0	0	**11**
DUWO	**10**	0	0	0	0	**10**
MALA	0	0	**5**	0	2	**7**
SCRO	**7**	0	0	0	0	**7**
GRBU	2	0	**4**	0	0	**6**
AUHO	0	0	**5**	0	0	**5**
TASC**	0	**5**	0	0	0	**5**
STHO**	**5**	0	0	0	0	**5**
EUGR*	0	0	0	**5**	0	**5**
TRMA	0	0	0	**3**	1	**4**
YEBL	**3**	0	0	0	0	**3**
TATH**	0	0	**3**	0	0	**3**
BLCO	**3**	0	0	0	0	**3**
GOWH	**2**	0	0	0	0	**2**
BRFA	**2**	0	0	0	0	**2**
CRHO	0	0	**1**	0	0	**1**
OLWH	0	**1**	0	0	0	**1**
BEFI	**0**	0	0	0	0	**0**
DURO**	**0**	0	0	0	0	**0**
FACO	**0**	0	0	0	0	**0**
WESW	**0**	0	0	0	0	**0**
RALO	0	0	0	**0**	0	**0**
TOTAL	639	389	525	536	484	2573

AVERAGE ABUNDANCE PER PT. PER DAY BY SITE						
SPECIES	KR	BP	QD	SB	HO	AVERAGE ACROSS ALL SITES
BRTH	**1.92**	1.53	0.28	0.00	0.00	**0.75**
RODO*	0.00	0.00	0.30	**0.00**	2.55	**0.57**
HOSP*	0.00	**0.00**	0.00	1.38	1.39	**0.55**
EUBL*	**0.01**	0.14	0.17	1.00	0.55	**0.37**
COST*	0.00	0.00	**0.09**	1.04	0.64	**0.36**
FOR A	0.76	0.40	0.38	0.10	0.13	**0.35**
YEHO**	0.90	**0.64**	0.10	0.00	0.00	**0.33**
SPPA	1.04	**0.35**	0.11	**0.00**	0.00	**0.30**
SIEY	0.14	0.33	0.00	**0.86**	0.04	**0.27**
MULO	0.00	0.00	**1.07**	0.00	0.00	**0.21**
LIWA	0.00	0.17	0.13	**0.64**	0.10	**0.21**
YEWA**	**0.32**	0.27	0.23	0.09	0.00	**0.18**
EARO	0.00	0.00	**0.64**	0.08	0.04	**0.15**
NOMI	0.00	0.00	**0.66**	0.00	0.00	**0.13**
BLHO**	0.50	0.08	0.03	0.00	**0.00**	**0.12**
AUMA	**0.03**	0.00	0.46	0.01	0.00	**0.10**
STPA	0.28	0.05	**0.16**	0.00	0.00	**0.10**
SPTU*	**0.00**	0.00	0.00	0.12	0.30	**0.08**
GRFA	**0.19**	0.15	0.04	0.01	0.00	**0.08**
NHHO	0.02	0.08	0.00	0.28	0.00	**0.08**
SUCO	0.00	0.12	**0.01**	0.17	0.00	**0.06**
BRBR	0.00	**0.26**	0.00	0.00	0.00	**0.05**
GRCU	0.16	0.06	0.02	0.00	**0.00**	**0.05**
GRRO**	**0.12**	0.05	0.00	0.06	0.00	**0.05**
EUGL*	0.00	0.08	0.08	**0.02**	0.00	**0.04**
SUFA	0.09	**0.04**	0.02	0.00	0.00	**0.03**
GRSH	0.08	**0.05**	0.00	0.00	0.00	**0.03**
EASP	**0.08**	0.05	0.00	0.00	0.00	**0.03**
LAKO*	**0.08**	0.03	0.01	0.01	0.00	**0.02**
DUWO	0.11	0.00	0.00	0.00	**0.00**	**0.02**
SCRO	**0.08**	0.00	0.00	0.00	0.00	**0.02**
MALA	**0.00**	0.00	0.05	0.00	0.02	**0.01**
TASC**	0.00	0.06	**0.00**	0.00	0.00	**0.01**
GRBU	**0.02**	0.00	0.04	0.00	0.00	**0.01**
STHO**	0.06	0.00	0.00	0.00	**0.00**	**0.01**
EUGR*	0.00	**0.00**	0.00	0.06	0.00	**0.01**
AUHO	**0.00**	0.00	0.05	0.00	0.00	**0.01**
TRMA	0.00	0.00	0.00	**0.03**	0.01	**0.01**
YEBL	**0.03**	0.00	0.00	0.00	0.00	**0.01**
BLCO	0.03	0.00	0.00	**0.00**	0.00	**0.01**
TATH**	**0.00**	0.00	0.03	0.00	0.00	**0.01**
GOWH	0.02	0.00	**0.00**	0.00	0.00	**0.00**
BRFA	**0.02**	0.00	0.00	0.00	0.00	**0.00**
OLWH	0.00	0.01	**0.00**	0.00	0.00	**0.00**
CRHO	0.00	**0.00**	0.01	0.00	0.00	**0.00**
BEFI	**0.00**	0.00	0.00	0.00	0.00	**0.00**
DURO**	**0.00**	0.00	0.00	0.00	0.00	**0.00**
FACO	**0.00**	0.00	0.00	0.00	0.00	**0.00**
WESW	**0.00**	0.00	0.00	0.00	0.00	**0.00**
RALO	0.00	0.00	0.00	**0.00**	0.00	**0.00**

APPENDIX IV: BIRD GROUP SPECIES COMPOSITION AND NUMBER

INTRODUCED GROUP			**THORNBILL GROUP**	
SPECIES	**#**		**SPECIES**	**#**
COST*	163		BRTH	317
EUBL*	168		SIEY	124
EUGL*	20		SPPA	132
EUGR*	5		STPA	50
HOSP*	187		TASC**	10
LAKO*	10		TATH**	3
RODO*	210		**TOTAL**	**636**
SPTU*	37			
TOTAL	**800**			
HONEYEATER GROUP			**ROSELLA GROUP**	
SPECIES	**#**		**SPECIES**	**#**
BLHO**	54		EARO	75
CRHO	1		GRRO**	20
EASP	15		MULO	109
LIWA	96		SUCO	48
NHHO	33		YEBL	3
NOMI	71		**TOTAL**	**255**
STHO**	5			
YEHO**	147			
YEWA**	82			
TOTAL	**504**			
CORVID GROUP			**THRUSH GROUP**	
SPECIES	**#**		**SPECIES**	**#**
AUMA	54		BLCO	3
FOR A	161		DUWO	10
GRBU	6		GOWH	3
GRCU	21		GRFA	46
TOTAL	**242**		GRSH	12
			OLWH	5
			SCRO	13
			SUFA	14
			TOTAL	**107**
BRONZEWING GROUP			**LAPWING GROUP**	
SPECIES	**#**		**SPECIES**	**#**
BRBR	21		MALA	7
TOTAL	**21**		**TOTAL**	**7**
RAPTOR GROUP			**SWALLOW GROUP**	
SPECIES	**#**		**SPECIES**	**#**
AUHO	4		TRMA	4
BRFA	2		**TOTAL**	**4**
TOTAL	**6**			

APPENDIX V: PLANT SPECIES PERCENTAGE FREQUENCY OF OCCURENCE BY BROAD HABITAT TYPE

SPECIES NAME	KW	BW	DW	UP	US	AVERAGE % OF PTS FOUND AT
Lomandra longifolia	**93.33**	53.85	58.33	0.00	0.00	**41.10**
Bursaria spinosa	26.67	**92.31**	50.00	11.76	11.76	**38.50**
Themeda triandra	33.33	61.54	**91.67**	0.00	0.00	**37.31**
*Plantago lanceolata**	60.00	30.77	**83.33**	0.00	5.88	**36.00**
Eucalyptus globulus	**86.67**	46.15	8.33	11.76	0.00	**30.58**
Austrostipa spp.	26.67	**69.23**	50.00	0.00	0.00	**29.18**
Lepidosperma laterale	6.67	61.54	**66.67**	0.00	0.00	**26.97**
Dodonaea viscose	20.00	**53.85**	41.67	17.65	0.00	**26.63**
*Dactylus glomerata**	33.33	15.38	**66.67**	0.00	5.88	**24.25**
Poa rodwayi	**60.00**	0.00	50.00	0.00	0.00	**22.00**
Astroloma humifusum	33.33	**53.85**	16.67	0.00	0.00	**20.77**
Eucalyptus viminalis	20.00	0.00	**83.33**	0.00	0.00	**20.67**
Allocasuarina verticillata	0.00	30.77	**66.67**	0.00	5.88	**20.66**
*Centaurium erythraea**	**46.67**	23.08	33.33	0.00	0.00	**20.62**
Juncus spp.	40.00	**61.54**	0.00	0.00	0.00	**20.31**
*Eucalyptus pulchella***	**73.33**	0.00	8.33	5.88	11.76	**19.86**
Austrodanthonia spp.	**46.67**	15.38	33.33	0.00	0.00	**19.08**
Acacia dealbata	0.00	**61.54**	0.00	23.53	5.88	**18.19**
Olearia ramulose	6.67	38.46	**41.67**	0.00	0.00	**17.36**
Poa sp.	0.00	**30.77**	0.00	23.53	29.41	**16.74**
Lissanthe strigose	26.67	**30.77**	25.00	0.00	0.00	**16.49**
Bossiaea prostrata	20.00	23.08	**33.33**	0.00	0.00	**15.28**
Acaena echinate	0.00	0.00	**75.00**	0.00	0.00	**15.00**
*Urospermum dalechampii**	0.00	0.00	**75.00**	0.00	0.00	**15.00**
Acacia melanoxylon	26.67	**30.77**	16.67	0.00	0.00	**14.82**
Eucalyptus ovata	20.00	**53.85**	0.00	0.00	0.00	**14.77**
Cotoneaster spp.*	30.77	**30.77**	0.00	0.00	11.76	**14.66**
Acacia genistifolia	0.00	0.00	**66.67**	0.00	5.88	**14.51**
Senecio quadridentatus	**46.67**	0.00	25.00	0.00	0.00	**14.33**
*Taraxacum officinale**	0.00	**61.54**	0.00	0.00	5.88	**13.48**
*Leptospermum grandiflorum***	0.00	0.00	0.00	**41.18**	23.53	**12.94**
Banksia marginate	**33.33**	30.77	0.00	0.00	0.00	**12.82**
Beyeria viscosa	0.00	**61.54**	0.00	0.00	0.00	**12.31**
Plantago varia	13.33	**30.77**	16.67	0.00	0.00	**12.15**
Hardenbergia violacea	0.00	0.00	0.00	**35.29**	23.53	**11.76**
*Agrostis capillaries**	20.00	**38.46**	0.00	0.00	0.00	**11.69**
Goodenia ovata	0.00	15.38	0.00	**23.53**	17.65	**11.31**
*Foeniculum vulgare**	0.00	0.00	8.33	11.76	**35.29**	**11.08**
Pultenaea juniperina	**40.00**	15.38	0.00	0.00	0.00	**11.08**
Eucalyptus spp. *(M)*	0.00	0.00	0.00	**47.06**	5.88	**10.59**
Pyracantha spp.*	0.00	0.00	0.00	**29.41**	23.53	**10.59**
Sambucus spp.*	0.00	0.00	0.00	**41.18**	11.76	**10.59**
Clematis spp.*	0.00	0.00	0.00	**47.06**	5.88	**10.59**
Diosma spp.*	0.00	0.00	0.00	**41.17**	11.76	**10.59**
Oxalis sp.*	6.67	0.00	**33.33**	11.76	0.00	**10.35**
Cupressus spp.*	0.00	0.00	8.33	**23.53**	17.65	**9.90**
Notelaea ligustrina	0.00	**30.77**	0.00	**11.76**	**5.88**	**9.68**
*Ulex europaeus**	**40.00**	0.00	8.33	0.00	0.00	**9.67**

Leptospermum scoparium	**40.00**	7.69	0.00	0.00	0.00	**9.54**
Acacia mearnsii	0.00	0.00	**41.67**	0.00	5.88	**9.51**
Callistemon spp. *(M)*	0.00	0.00	0.00	**35.29**	11.76	**9.41**
Viola spp.*	0.00	0.00	0.00	**17.65**	29.41	**9.41**
Chenopodium spp.*	0.00	0.00	0.00	**17.65**	**29.41**	**9.41**
Oxalis perennans	**40.00**	0.00	0.00	0.00	5.88	**9.18**
*Briza maxima**	20.00	0.00	**25.00**	0.00	0.00	**9.00**
Exocarpos cupressiformis	**33.33**	0.00	8.33	0.00	0.00	**8.33**
*Hordeum vulgare**	0.00	0.00	0.00	11.76	**29.41**	**8.24**
unknown shrub spp.	0.00	0.00	0.00	**35.29**	5.88	**8.24**
*Felicia amelloides**	0.00	0.00	0.00	17.65	**23.53**	**8.24**
*Poa annua**	0.00	0.00	0.00	17.65	**23.53**	**8.24**
*Olearia ericoides***	**33.33**	7.69	0.00	0.00	0.00	**8.21**
Polystichum proliferum	0.00	**38.46**	0.00	0.00	0.00	**7.69**
Acaena novae-zelandiae	13.33	**23.08**	0.00	0.00	0.00	**7.28**
Olearia argophylla	13.33	**23.08**	0.00	0.00	0.00	**7.28**
*Geranium domesticum**	6.67	0.00	0.00	**23.53**	5.88	**7.22**
Ozothamnus ferrugineus	**20.00**	15.38	0.00	0.00	0.00	**7.08**
Convolvulvus spp.*	0.00	0.00	0.00	**29.41**	5.88	**7.06**
Helleborus spp.*	0.00	0.00	0.00	0.00	**35.29**	**7.06**
Osteospermum spp.*	0.00	0.00	0.00	**17.65**	**17.65**	**7.06**
*Photinia robusta**	0.00	0.00	0.00	**17.65**	**17.65**	**7.06**
*Holcus lanatus**	**26.67**	0.00	8.33	0.00	0.00	**7.00**
*Petrorhagia prolifera**	0.00	0.00	**33.33**	0.00	0.00	**6.67**
*Oxalis corniculata**	0.00	**30.77**	0.00	0.00	0.00	**6.15**
*Rubus fruticosus**	6.67	**15.38**	8.33	0.00	0.00	**6.08**
*Conyza bonariensis**	**6.67**	0.00	0.00	5.88	**17.65**	**6.04**
*Euphorbia peplus**	0.00	0.00	0.00	**17.65**	11.76	**5.88**
Scutellaria spp.*	0.00	0.00	0.00	11.76	**17.65**	**5.88**
Zieria spp.*	0.00	0.00	0.00	**23.53**	5.88	**5.88**
Hakea spp. *(M)*	0.00	0.00	0.00	**23.52**	5.88	**5.88**
Dillwynia cinerascens	**20.00**	7.69	0.00	0.00	0.00	**5.54**
Gonocarpus tetragynus	**20.00**	7.69	0.00	0.00	0.00	**5.54**
Ozathamnus obcordatus	**20.00**	7.69	0.00	0.00	0.00	**5.54**
*Cedrus deodara**	0.00	0.00	**25.00**	0.00	0.00	**5.00**
Senecio glomeratus	0.00	0.00	**25.00**	0.00	0.00	**5.00**
*Erharta erecta**	0.00	0.00	0.00	**17.65**	5.88	**4.71**
Agathis australis (M)	0.00	0.00	0.00	**11.76**	**11.76**	**4.71**
*Nyssa sylvatica**	0.00	0.00	0.00	**11.76**	**11.76**	**4.71**
*Symphoricarpos occidentalis**	0.00	0.00	0.00	**23.53**	0.00	**4.71**
Aster ssp.*	0.00	0.00	0.00	**17.65**	5.88	**4.71**
Allocasuarina littoralis	0.00	**23.08**	0.00	0.00	0.00	**4.62**
*Bedfordia linearis***	0.00	**23.08**	0.00	0.00	0.00	**4.62**
*Pimelea nivea***	0.00	**23.08**	0.00	0.00	0.00	**4.62**
*Cirsium vulgare**	**13.33**	0.00	8.33	0.00	0.00	**4.33**
*Bedfordia salicina***	6.67	**7.69**	0.00	0.00	5.88	**4.05**
Cassinia aculeate	**20.00**	0.00	0.00	0.00	0.00	**4.00**
Leptorhynchos squamatus	**20.00**	0.00	0.00	0.00	0.00	**4.00**
Pteridium esculentum	**20.00**	0.00	0.00	0.00	0.00	**4.00**
Senecio linearifolius	**20.00**	0.00	0.00	0.00	0.00	**4.00**
Grevillea robingordon (M)	**13.33**	0.00	0.00	5.88	0.00	**3.84**
*Lochroma grandiflora**	0.00	0.00	0.00	**17.65**	0.00	**3.53**

Melalucca spp.	0.00	0.00	0.00	0.00	**17.65**	**3.53**
Metrosideros spp.*	0.00	0.00	0.00	**17.65**	0.00	**3.53**
Palmae sp.*	0.00	0.00	0.00	**17.65**	0.00	**3.53**
Rosa spp.*	0.00	0.00	0.00	**17.65**	0.00	**3.53**
Rumex spp.*	0.00	0.00	0.00	0.00	**17.65**	**3.53**
Sagina procunbens *	0.00	0.00	0.00	**17.65**	0.00	**3.53**
Tropaeolum spp.*	0.00	0.00	0.00	**17.65**	0.00	**3.53**
Berberis sp.*	0.00	0.00	0.00	**11.76**	5.88	**3.53**
*Betula pendula**	0.00	0.00	0.00	5.88	**11.76**	**3.53**
Crocus sp.*	0.00	0.00	0.00	**11.76**	5.88	**3.53**
Gazania spp.*	0.00	0.00	0.00	**11.76**	5.88	**3.53**
Lepidium pseudotasmanicum ®	0.00	0.00	**16.67**	0.00	0.00	**3.33**
Pentapogon quadrifidus	0.00	0.00	**16.67**	0.00	0.00	**3.33**
Ranunculus lappaceus	0.00	0.00	**16.67**	0.00	0.00	**3.33**
Wahlenbergia stricta	0.00	0.00	**16.67**	0.00	0.00	**3.33**
Hypericum gramineum	0.00	**7.69**	8.33	0.00	0.00	**3.21**
*Clematis gentianoides***	0.00	**15.38**	0.00	0.00	0.00	**3.08**
Correa reflexa	0.00	**15.38**	0.00	0.00	0.00	**3.08**
Cynoglossum suaveolens	0.00	**15.38**	0.00	0.00	0.00	**3.08**
Leucopogon virgatus	0.00	**15.38**	0.00	0.00	0.00	**3.08**
Prostanthera lasianthos	0.00	**15.38**	0.00	0.00	0.00	**3.08**
Pultenaea daphnoides var. obcordate	0.00	**15.38**	0.00	0.00	0.00	**3.08**
Elymus scaber	6.67	0.00	**8.33**	0.00	0.00	**3.00**
*Rosa rubiginosa**	6.67	0.00	**8.33**	0.00	0.00	**3.00**
*Sanguisorba minor**	0.00	0.00	**8.33**	5.88	0.00	**2.84**
*Hypochaeris radicata**	0.00	0.00	**8.33**	5.88	0.00	**2.84**
Microsorum pustulatum	0.00	**7.69**	0.00	5.88	0.00	**2.71**
Allocausarina spp.	**13.33**	0.00	0.00	0.00	0.00	**2.67**
*Arrhenatherum elatius**	**13.33**	0.00	0.00	0.00	0.00	**2.67**
Arthropodium milleflorum	**13.33**	0.00	0.00	0.00	0.00	**2.67**
Daviesia ulicifolia	**13.33**	0.00	0.00	0.00	0.00	**2.67**
Eucalyptus amygdalina	**13.33**	0.00	0.00	0.00	0.00	**2.67**
*Leontodon taraxacoides**	**13.33**	0.00	0.00	0.00	0.00	**2.67**
*Lomatia tinctoria***	**13.33**	0.00	0.00	0.00	0.00	**2.67**
Stylidium graminifolium	**13.33**	0.00	0.00	0.00	0.00	**2.67**
Einadia nutans	**6.67**	0.00	0.00	5.88	0.00	**2.51**
Olearia viscose	**6.67**	0.00	0.00	0.00	5.88	**2.51**
Agonis flexuosa (M)	0.00	0.00	0.00	**5.88**	**5.88**	**2.35**
Ailianthus sp.*	0.00	0.00	0.00	**11.76**	0.00	**2.35**
*Bellis perennis**	0.00	0.00	0.00	**11.76**	0.00	**2.35**
Brassica spp.*	0.00	0.00	0.00	0.00	**11.76**	**2.35**
Callistemon citrinus	0.00	0.00	0.00	**11.76**	0.00	**2.35**
Clethra spp.*	0.00	0.00	0.00	**11.76**	0.00	**2.35**
Correa (dwarf)	0.00	0.00	0.00	**5.88**	**5.88**	**2.35**
Correa backhouseana	0.00	0.00	0.00	**5.88**	**5.88**	**2.35**
*Cotoneaster microphyllus**	0.00	0.00	0.00	0.00	**11.76**	**2.35**
Cynodon dactylon (M)	0.00	0.00	0.00	**11.76**	0.00	**2.35**
*Erigeron karvinskianus**	0.00	0.00	0.00	**5.88**	**5.88**	**2.35**
*Galium aparine**	0.00	0.00	0.00	**5.88**	**5.88**	**2.35**
*Ilex spp.**	0.00	0.00	0.00	0.00	**11.76**	**2.35**
*Juniperus spp.**	0.00	0.00	0.00	**11.76**	0.00	**2.35**

*Lolium perenne**	0.00	0.00	0.00	0.00	**11.76**	**2.35**
Photinia spp.*	0.00	0.00	0.00	**11.76**	0.00	**2.35**
*Polygonum capitatum**	0.00	0.00	0.00	**5.88**	**5.88**	**2.35**
*Quercus robur**	0.00	0.00	0.00	**5.88**	**5.88**	**2.35**
Robinia spp.*	0.00	0.00	0.00	0.00	**11.76**	**2.35**
Rosemarinus spp.*	0.00	0.00	0.00	0.00	**11.76**	**2.35**
Senecio spp.*	0.00	0.00	0.00	0.00	**11.76**	**2.35**
*Stachys byzantina**	0.00	0.00	0.00	**11.76**	0.00	**2.35**
Tilia spp.*	0.00	0.00	0.00	**11.76**	0.00	**2.35**
Trifolium sp.*	0.00	0.00	0.00	0.00	**11.76**	**2.35**
Westringia sp.*	0.00	0.00	0.00	**11.76**	0.00	**2.35**
*Acacia pycnantha**	0.00	0.00	**8.33**	0.00	0.00	**1.67**
*Chrysanthemoides monilifera**	0.00	0.00	**8.33**	0.00	0.00	**1.67**
Chrysocephalum apiculatum	0.00	0.00	**8.33**	0.00	0.00	**1.67**
Acacia verticillate	0.00	**7.69**	0.00	0.00	0.00	**1.54**
Cassytha sp.	0.00	**7.69**	0.00	0.00	0.00	**1.54**
Coprosma quadrifida	0.00	**7.69**	0.00	0.00	0.00	**1.54**
Deyeuxia quadriseta	0.00	**7.69**	0.00	0.00	0.00	**1.54**
*Pimelea cinerea***	0.00	**7.69**	0.00	0.00	0.00	**1.54**
Pittosporum bicolour	0.00	**7.69**	0.00	0.00	0.00	**1.54**
Pomaderris apetala	0.00	**7.69**	0.00	0.00	0.00	**1.54**
*Rorippa nastursium-aquaticum**	0.00	**7.69**	0.00	0.00	0.00	**1.54**
Acacia riceana	**6.67**	0.00	0.00	0.00	0.00	**1.33**
Dianella revolute	**6.67**	0.00	0.00	0.00	0.00	**1.33**
Diplarrena moraea	**6.67**	0.00	0.00	0.00	0.00	**1.33**
Exocarpos strictus	**6.67**	0.00	0.00	0.00	0.00	**1.33**
Hakea lissosperma	**6.67**	0.00	0.00	0.00	0.00	**1.33**
Helichrysum scorpioides	**6.67**	0.00	0.00	0.00	0.00	**1.33**
Leptomeria drupacea	**6.67**	0.00	0.00	0.00	0.00	**1.33**
Linum marginale	**6.67**	0.00	0.00	0.00	0.00	**1.33**
Linum sp.	**6.67**	0.00	0.00	0.00	0.00	**1.33**
Olearia myrsinoides	**6.67**	0.00	0.00	0.00	0.00	**1.33**
Olearia phlogopappa	**6.67**	0.00	0.00	0.00	0.00	**1.33**
Opercularia varia	**6.67**	0.00	0.00	0.00	0.00	**1.33**
Veronica gracilis	**6.67**	0.00	0.00	0.00	0.00	**1.33**
Homoranthus flavescens (M)	0.00	0.00	0.00	**5.88**	0.00	**1.18**
*Abelia grandiflora**	0.00	0.00	0.00	**5.88**	0.00	**1.18**
Acacia floribunda (M)	0.00	0.00	0.00	0.00	**5.88**	**1.18**
Acacia mucronata	0.00	0.00	0.00	**5.88**	0.00	**1.18**
Acacia spp.	0.00	0.00	0.00	**5.88**	0.00	**1.18**
*Acanthus mollis**	0.00	0.00	0.00	0.00	**5.88**	**1.18**
*Achillea millefolium**	0.00	0.00	0.00	0.00	**5.88**	**1.18**
Agapanthus spp.*	0.00	0.00	0.00	0.00	**5.88**	**1.18**
Agonis spp. *(M)*	0.00	0.00	0.00	0.00	**5.88**	**1.18**
*Allocausarina crassa***	0.00	0.00	0.00	0.00	**5.88**	**1.18**
*Alyssum spp.**	0.00	0.00	0.00	0.00	**5.88**	**1.18**
*Amaranthus spp.**	0.00	0.00	0.00	**5.88**	0.00	**1.18**
Araucaria sp.*	0.00	0.00	0.00	0.00	**5.88**	**1.18**
*Aucuba japonica**	0.00	0.00	0.00	0.00	**5.88**	**1.18**
Aucuba spp.*	0.00	0.00	0.00	0.00	**5.88**	**1.18**
*Aunus rubra**	0.00	0.00	0.00	0.00	**5.88**	**1.18**
Bromus spp.*	0.00	0.00	0.00	**5.88**	0.00	**1.18**

*Camellia japonica**	0.00	0.00	0.00	**5.88**	0.00	**1.18**
*Capsella bursa-pastoris**	0.00	0.00	0.00	0.00	**5.88**	**1.18**
*Cardamine spp.**	0.00	0.00	0.00	**5.88**	0.00	**1.18**
Centranthus sp.*	0.00	0.00	0.00	**5.88**	0.00	**1.18**
Cheanomeles spp.*	0.00	0.00	0.00	**5.88**	0.00	**1.18**
Chloris sp.*	0.00	0.00	0.00	0.00	**5.88**	**1.18**
*Choisya ternata**	0.00	0.00	0.00	**5.88**	0.00	**1.18**
Chrysantemum spp.*	0.00	0.00	0.00	0.00	**5.88**	**1.18**
*Coprosma repens**	0.00	0.00	0.00	0.00	**5.88**	**1.18**
Correa alba	0.00	0.00	0.00	0.00	**5.88**	**1.18**
Correa spp. *(M)*	0.00	0.00	0.00	**5.88**	0.00	**1.18**
Crassula sp.*	0.00	0.00	0.00	0.00	**5.88**	**1.18**
Crataegus sp.*	0.00	0.00	0.00	**5.88**	0.00	**1.18**
Cyperus spp.*	0.00	0.00	0.00	0.00	**5.88**	**1.18**
Cytisus sp.*	0.00	0.00	0.00	0.00	**5.88**	**1.18**
Deutzia sp.*	0.00	0.00	0.00	0.00	**5.88**	**1.18**
Dianthus sp.*	0.00	0.00	0.00	**5.88**	0.00	**1.18**
Elaeagnus sp.*	0.00	0.00	0.00	0.00	**5.88**	**1.18**
Erica sp.*	0.00	0.00	0.00	0.00	**5.88**	**1.18**
*Erodium moschatum**	0.00	0.00	0.00	0.00	**5.88**	**1.18**
Escallonia sp.*	0.00	0.00	0.00	0.00	**5.88**	**1.18**
Eucalyptus ficifolia (M)	0.00	0.00	0.00	**5.88**	0.00	**1.18**
Fagus spp.*	0.00	0.00	0.00	0.00	**5.88**	**1.18**
*Fraxinus excelsior**	0.00	0.00	0.00	**5.88**	0.00	**1.18**
Fraxinus sp.*	0.00	0.00	0.00	0.00	**5.88**	**1.18**
*Ginkgo biloba**	0.00	0.00	0.00	0.00	**5.88**	**1.18**
Grevillea sp. (M)	0.00	0.00	0.00	0.00	**5.88**	**1.18**
Hebe sp.*	0.00	0.00	0.00	0.00	**5.88**	**1.18**
*Hedera helix**	0.00	0.00	0.00	0.00	**5.88**	**1.18**
Kunzea ambigua	0.00	0.00	0.00	0.00	**5.88**	**1.18**
Kunzea sp.	0.00	0.00	0.00	**5.88**	0.00	**1.18**
Lagunaria patersonii (M)	0.00	0.00	0.00	**5.88**	0.00	**1.18**
Lavandula spp.*	0.00	0.00	0.00	**5.88**	0.00	**1.18**
Leptospermum phylicoides (M)	0.00	0.00	0.00	**5.88**	0.00	**1.18**
Leptospermum sp. *(M)*	0.00	0.00	0.00	**5.88**	0.00	**1.18**
*Leycesteria formosa**	0.00	0.00	0.00	**5.88**	0.00	**1.18**
Ligustrum sp.*	0.00	0.00	0.00	0.00	**5.88**	**1.18**
*Liquidambar styraciflua**	0.00	0.00	0.00	**5.88**	0.00	**1.18**
*Lonicera japonica**	0.00	0.00	0.00	**5.88**	0.00	**1.18**
Lonicera sp.*	0.00	0.00	0.00	0.00	**5.88**	**1.18**
*Magnolia campbellii**	0.00	0.00	0.00	0.00	**5.88**	**1.18**
*Magnolia grandiflora**	0.00	0.00	0.00	0.00	**5.88**	**1.18**
Magnolia sp.*	0.00	0.00	0.00	0.00	**5.88**	**1.18**
*Malus domestica**	0.00	0.00	0.00	0.00	**5.88**	**1.18**
*Malva moschata**	0.00	0.00	0.00	0.00	**5.88**	**1.18**
Melaleuca armillaris	0.00	0.00	0.00	0.00	**5.88**	**1.18**
Melaleuca gibbosa	0.00	0.00	0.00	**5.88**	0.00	**1.18**
*Michelia doltsopa**	0.00	0.00	0.00	**5.88**	0.00	**1.18**
Olearia lirata	0.00	0.00	0.00	0.00	**5.88**	**1.18**
Ozothamnus sp.	0.00	0.00	0.00	**5.88**	0.00	**1.18**
Paeonia sp.*	0.00	0.00	0.00	**5.88**	0.00	**1.18**
Pelargonium spp.*	0.00	0.00	0.00	0.00	**5.88**	1.18

*Philadelphus spp.**	0.00	0.00	0.00	0.00	**5.88**	**1.18**
Phormium tenax	0.00	0.00	0.00	0.00	**5.88**	**1.18**
Picris sp.*	0.00	0.00	0.00	0.00	**5.88**	**1.18**
*Pinus coulteri**	0.00	0.00	0.00	**5.88**	0.00	**1.18**
Pittosporum sp.*	0.00	0.00	0.00	**5.88**	0.00	**1.18**
*Plantago coronopus**	0.00	0.00	0.00	**5.88**	0.00	**1.18**
*Plumbago auriculate**	0.00	0.00	0.00	**5.88**	0.00	**1.18**
*Polycarpon tetraphyllum**	0.00	0.00	0.00	**5.88**	0.00	**1.18**
*Polygonum aviculare**	0.00	0.00	0.00	0.00	**5.88**	**1.18**
Prunus sp.*	0.00	0.00	0.00	0.00	**5.88**	**1.18**
*Rhododendron spp.**	0.00	0.00	0.00	**5.88**	0.00	**1.18**
*Scabiosa atropurpurea**	0.00	0.00	0.00	0.00	**5.88**	**1.18**
*Senecio vulgaris**	0.00	0.00	0.00	0.00	**5.88**	**1.18**
Sequoia sp.*	0.00	0.00	0.00	0.00	**5.88**	**1.18**
*Solanum nigrum**	0.00	0.00	0.00	**5.88**	0.00	**1.18**
Sonchus sp.*	0.00	0.00	0.00	0.00	**5.88**	**1.18**
Sorbus sp.*	0.00	0.00	0.00	0.00	**5.88**	**1.18**
*Stellaria media**	0.00	0.00	0.00	0.00	**5.88**	**1.18**
*Tecoma capensis**	0.00	0.00	0.00	**5.88**	0.00	**1.18**
Thryptomene micrantha	0.00	0.00	0.00	**5.88**	0.00	**1.18**
Thuja sp.*	0.00	0.00	0.00	0.00	**5.88**	**1.18**
Ulmus sp.*	0.00	0.00	0.00	0.00	**5.88**	**1.18**
unknown conifer spp.*	0.00	0.00	0.00	0.00	**5.88**	**1.18**
unknown deciduous spp.*	0.00	0.00	0.00	0.00	**5.88**	**1.18**
unknown evergreeen spp.*	0.00	0.00	0.00	**5.88**	0.00	**1.18**
unknown flower spp.*	0.00	0.00	0.00	0.00	**5.88**	**1.18**
unknown grass spp.*	0.00	0.00	0.00	0.00	**5.88**	**1.18**
unknown herb spp.*	0.00	0.00	0.00	0.00	**5.88**	**1.18**
unknown shrub spp.*	0.00	0.00	0.00	0.00	**5.88**	**1.18**
*Verbascum thapsus**	0.00	0.00	0.00	0.00	**5.88**	**1.18**
*Viola odorata**	0.00	0.00	0.00	0.00	**5.88**	**1.18**

Note: Tasmanian plant names according to the Tasmanian Herbarium (2005) and garden plant names according to the Royal Horticultural Society (2006-7). See references for details. *= introduced, **= endemic, (M)= mainland native and R= rare plant. KW= Knocklofty woodland, BW= Bicentennial woodland, DW= Domain woodland, UP= urban parks, US= urban streets. Location where the species is most frequently found is in bold.

APPENDIX VI: RAW INVERTEBRATE DATA
Knocklofty Reserve

		KL1A	KL1B	KL1C	KL1D	KL1E	KL1F	KL1G	KL1H	KL2A	KL2B	KL2C	KL2D	KL2E	KL2F	KL2G	KL2H
FAMILY	GENUS SPECIES	*Euc. pulchella*	*Euc. pulchella*	*Euc ovata*	*Euc ovata*	*Acacia dealbata*	*Acacia dealbata*	*Bursaria spinosa*	*Bursaria spinosa*	*Acacia dealbata*	*Acacia dealbata*	*Allocasuarina verticillata*	*Monotoca*	*Euc. pulchella*	*Euc. pulchella*	*Euc. pulchella*	*Euc. pulchella*
Anystidae		1	0	0	0	0	2	0	0	1	0	0	0	0	0	0	0
Araneidae	*Araneus*	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Bethylidae		0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Bothriuridae		0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Brentidae	*Auletobius melanocephalus*	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Carabidae	*Demetrida*	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Carabidae	Lebiini small	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Carabidae	Lebiini black	0	0	0	0	0	0	0	0	0	0	0	0	2	0	3	0
Carabidae	Lebiini 4spot	0	0	0	0	0	0	0	0	0	0	0	0	10	5	3	0
Carposinidae	moth	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Chalcidae		0	0	0	0	0	0	0	0	0	0	0	0	0	2	5	0
Chloropidae		0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Chrysomelida	*Arsipoda*	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Chrysomelida	*Cryptocephalus* blue	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Chrysomelida	*Peltoschema hamadryas*	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Cicadellidae		0	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0
Cleridae		0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Coccinellidae	*Rhizobius* 6spot	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Curculionidae	*Baris*	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Curculionidae	*Poropterus*	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Curculionidae	Tychiini	0	0	0	0	0	0	0	0	0	2	0	2	0	0	0	0
Curculionidae	*Merimnetes*	1	0	0	0	0	0	0	0	4	1	0	0	0	1	6	1
Erythraeidae		0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Eurymelidae	Eurymela	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Formicidae	*Camponotus claripes*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Formicidae	*Camponotus consobrinus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Formicidae	*Iridomyrmex*	0	0	0	1	0	0	0	1	2	3	0	0	1	0	1	0
Geometridae	larva L2	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0
Gnaphosidae		0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0
Lasiocampida	larva L3	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Lygaeidae	ant mimic	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
microwasp		0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0
Miridae		0	0	0	0	0	0	1	0	0	3	0	0	0	0	0	0
patterned		2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Polydesmida		0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Pseudoscorpionida		0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Psyllidae		0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Salticidae	*Holoplatys*	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Salticidae	black	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Sciaridae		0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Sminthuridae	*Katianna* giant	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0
Theridiidae	small b&w	0	0	0	0	0	1	0	0	2	1	0	2	0	0	0	0
Thomisidae	*Stephanopis*	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Thomisidae		0	0	1	0	0	0	1	0	2	0	0	0	0	0	0	0
Thripidae	black large	0	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0
Tingidae		0	0	0	0	0	0	2	0	0	1	0	0	0	0	0	0
Trombiculidae		2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Zodariidae		0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Zopheridae		0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0

Bicentennial Park

		BP1A	BP1B	BP1C	BP1D	BP1E	BP1F	BP1G	BP1H	BP2A	BP2B	BP2C	BP2D	BP2E	BP2F	BP2G	BP2H
FAMILY	GENUS SPECIES	*Bursaria spinosa*	*Acacia melanoxylon*	*Bedfordia salicina*	*Acacia melanoxylon*	*Eucalyptus ovata*	*Eucalyptus pulchella*	*Eucalyptus pulchella*	*Eucalyptus ovata*	*Bursaria spinosa*	*Bursaria spinosa*	*Bursaria spinosa*	*Bursaria spinosa*	*Bursaria spinosa*	*Bursaria spinosa*	*Bursaria spinosa*	*Bursaria spinosa*
Anystidae		1	3	0	0	0	0	0	0	1	2	1	0	2	1	1	2
Aphididae		0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Araneidae	*Araneus*	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Blatellidae		0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0
Carabidae	Lebiini black	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Carabidae	*Demetrida*	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Carabidae	Lebiini small	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Chironomidae		0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Curculionidae	*Merimnetes*	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Curculionidae	Tychiini	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Entomobryidae		0	0	0	0	0	0	0	0	0	0	2	0	0	1	0	0
Erythraeidae		0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Formicidae	*Iridomyrmex*	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0
Formicidae	*Iridomyrmex* male	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Formicidae	*Myrmecia* male	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Gnaphosidae		0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Hemerobiidae	*Micromus tasmaniae*	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Lygaeidae	ant mimic	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
microwasp		0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0
Oecophoridae	moth	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Paronellidae		0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Philodromidae		0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Phoridae		0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Psocoptera		1	0	0	2	0	0	0	0	0	0	0	0	0	0	3	0
Psyllidae		0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Salticidae	*Opisthoncus*	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Tephritidae		0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Theridiidae	*Archaranea*	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0
Theridiidae	small b&w	1	0	1	0	0	0	0	0	0	0	2	2	4	0	1	0
Thomisidae		0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Zopheridae		0	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0

Queen's Domain

		QD1A	QD1B	QD1C	QD1D	QD1E	QD1F	QD1G	QD1H	QD2A	QD2B	QD2C	QD2D	QD2E	QD2F	QD2G	QD2H
FAMILY	GENUS SPECIES	*Bursaria or Dodonaea*	*Eucalyptus*	*Olearia ramulosa*	*Eucalyptus*	*Eucalyptus*	*Eucalyptus*	*Acacia dealbata*	*Acacia dealbata*	*Bursaria spinosa*	*Bursaria spinosa*	*Acacia melanoxylon*	*Eucalyptus viminalis*	*Allocasuarina littoralis*	*Allocasuarina littoralis*	*Eucalyptus viminalis*	*Eucalyptus viminalis*
Anystidae		0	1	0	2	0	0	0	0	0	0	2	0	0	0	0	0
Araneidae	*Araneus*	1	3	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Bethylidae		0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Chalcidae		0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Chloropidae		0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Chrysomelidae	*Cryptocephalus* blue	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Chrysomelidae	*Cryptocephalus* bronze	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Chrysomelidae	*Pyrgoides*	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Chrysomelidae	*Monolepta*	0	0	1	0	0	0	1	6	0	0	0	0	0	0	0	0
Cicadellidae		0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Coccidae		0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Coccinellidae	*Rhizobius*	1	1	3	0	0	0	0	1	0	0	0	0	1	0	0	0
Curculionidae	Tychiini	1	0	0	2	0	0	3	0	0	0	0	0	3	0	0	0
Erotylidae	*Thallis* blue	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Erythraeidae		0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Formicidae	*Iridomyrmex* queen	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Formicidae	*Camponotus claripes*	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
Formicidae	*Iridomyrmex*	1	0	0	0	1	1	0	1	0	0	3	0	1	0	0	0
Geometridae	larva L2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Gnaphosidae		0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Gracillariidae	moth	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Hemerobiidae	*Micromus tasmaniae*	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Julidae		0	1	0	0	3	2	0	0	0	0	0	0	0	0	0	0
Lamponidae	*Lampona cylindrata*	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Lepismatidae		0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Miridae		0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0
Pentatomidae		0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Phalacridae	*black*	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Psocoptera		0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0
Psychidae	*Cebysa leucotelus* moth	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Psyllidae		0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
Salticidae	*small*	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Sparassidae	*Delena cancerides*	0	0	0	0	2	1	0	0	0	0	0	0	0	0	1	1
Tenebrionidae	*Pteroheleus*	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Theridiidae	*Archaranea*	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Theridiidae	conical	0	0	0	0	0	0	0	0	1	2	0	0	1	0	0	0
Theridiidae	small b&w	3	2	6	0	0	0	3	0	1	0	0	1	0	0	0	0
Thomisidae		0	0	1	3	3	0	0	0	0	0	0	3	0	0	1	0
Thripidae	black large	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	larva pink	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
	Porcellio	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0

Sandy Bay

		SB1A	SB1B	SB1C	SB1D	SB1E	SB1F	SB1G	SB1H	SB2A	SB2B	SB2C	SB2D	SB2E	SB2F	SB2G	SB2H
FAMILY	GENUS SPECIES	*Acacia menziesii*	*Acacia melanoxylon*	*Allocasuarina verticillata*	*Eucalyptus*	*Melaleuca hypericifolia*	*Melaleuca squamea*	*Correa alba*	*Salix*	*Eucalyptus ficifolia*	*Melaleuca hypericifolia*	*Melaleuca hypericifolia*	*Melaleuca hypericifolia*	*Melaleuca hypericifolia*	*Melaleuca hypericifolia*	*Callistemon*	*Callistemon*
Anystidae		0	0	0	0	0	0	1	7	0	2	0	0	1	0	0	0
Aphididae		0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Bethylidae		0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Chironomidae		0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Chrysomelidae	*Paropsini*	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chrysomelidae	*Monolepta*	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coccinellidae	*Coccinella L*	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coccinellidae	*Rhizobius large red un*	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Coccinellidae	*Rhizobius*	1	0	0	3	0	0	0	0	0	0	0	0	0	1	0	0
Coniopterygidae		0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Curculionidae	*Scotasmus*	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Curculionidae	*medium*	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
Curculionidae	Tychiini	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
Elachistidae	moth	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Flatidae	*Siphanta acuta*	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Formicidae	***Linepithema humile***	36	0	1	40	1	0	16	0	9	1	6	8	1	0	0	0
Gastropoda		0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Gnaphosidae		0	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0
Gracillariidae	moth	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Latridiidae	Corticariinae	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0
microwasp		2	0	0	0	1	0	0	0	1	1	1	0	0	0	2	1
Miridae		0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Oxyopidae	*Oxyops*	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Philodromidae		0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	0
Psocoptera		0	0	0	1	0	0	0	1	1	3	0	1	0	1	2	1
Psyllidae		4	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Salticidae	*Opisthoncus*	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0
Salticidae	*small*	0	0	0	0	4	0	3	0	0	0	0	0	0	0	0	1
Stathmopodidae	*moth*	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Theridiidae	*Archaranea*	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Theridiidae	small b&w	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
Thomisidae	*Diaea*	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Thomisidae	*Stephanopis*	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Thomisidae	*Sidymella*	0	0	0	0	0	0	4	1	0	0	0	0	0	0	0	0
Thripidae	black large	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Trombiculidae		8	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Porcellio	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Hobart

FAMILY	GENUS SPECIES	HBA1A *Cotoneaster*	HBA1B	HBA1C *Ulmus*	HBA1D	HBA1E *Prunus*	HBA1F *Acer*	HBA1G *Acer*	HBA1H	HBA2B
Anisopodidae	Sylvicola	0	0	0	0	0	0	0	1	0
Anystidae		0	0	0	0	0	2	0	0	0
Apidae	***Bombus terrestris***	0	0	0	0	0	1	0	0	0
Coccinellidae	larva	0	0	0	0	0	2	0	0	0
Empididae		0	0	0	0	1	0	0	0	0
Erythraeidae		0	1	1	0	0	0	0	2	0
Flatidae	*Siphanta acuta*	0	0	0	0	1	0	0	0	0
Formicidae	***Linepithema humile***	0	0	0	0	0	4	0	0	0
Hemerobiidae	*Micromus tasmaniae*	0	0	0	0	0	1	0	0	0
Lygaeidae		0	0	0	0	0	0	0	9	0
Lymantriidae	larvaL3	0	0	0	0	1	0	0	0	0
microwasp		0	0	0	0	0	2	0	0	0
Miridae		0	0	0	0	1	6	0	0	4
Phalangiidae		0	1	0	0	0	0	0	0	0
Philodromidae		0	0	0	0	0	1	0	0	0
Psocoptera		0	0	0	0	0	0	0	0	1
Psyllidae		0	0	0	0	0	6	0	0	0
Sciaridae		0	0	0	0	0	1	0	0	0
Theridiidae	*Archaranea*	0	2	0	0	0	0	0	0	0
Theridiidae	small b&w	0	0	1	0	0	0	0	0	1
Thripidae		0	0	0	0	0	2	0	0	0
	Porcellio	0	1	0	0	0	0	0	0	0

APPENDIX VII: INVERTEBRATE SPECIES CODES

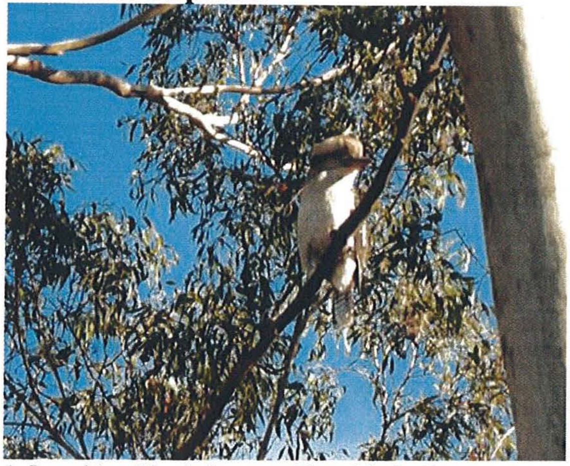
ORDER	FAMILY	GENUS SPECIES	SPECIES CODES
Acarina	Anystidae		**AcarAn**
Acarina	Erythraeidae		**AcarEr**
Acarina	Trombiculidae		**AcarTr**
Araneae	Araneidae	*Araneus*	**AranAr**
Araneae	Gnaphosidae		**AranGn**
Araneae	Lamponidae	*Lampona cylindrata*	**AranLa**
Araneae	Oxyopidae	*Oxyops*	**AranOxyo**
Araneae	Philodromidae		**AranPhil**
Araneae	Salticidae	black	**AranSaBl**
Araneae	Salticidae	*Holoplatys*	**AranSaHo**
Araneae	Salticidae	*Opisthoncus*	**AranSaOp**
Araneae	Salticidae	*small*	**AranSaSm**
Araneae	Sparassidae	*Delena cancerides*	**AranDele**
Araneae	Theridiidae	*Archaranea*	**AranThAr**
Araneae	Theridiidae	small b&w	**AranThBW**
Araneae	Theridiidae	conical	**AranThCo**
Araneae	Thomisidae	*Diaea*	**AranThDi**
Araneae	Thomisidae	*Sidymella*	**AranThSy**
Araneae	Thomisidae	*Stephanopis*	**AranThSt**
Araneae	Thomisidae		**AranTh**
Araneae	Zodariidae		**AranZo**
Blattodea	Blatellidae		**BlatBl**
Coleoptera	Brentidae	*Auletobius melanocephalus*	**ColeBr**
Coleoptera	Carabidae	Lebiini black	**ColeCaLB**
Coleoptera	Carabidae	*Demetrida*	**ColeCaDe**
Coleoptera	Carabidae	Lebiini 4spot	**ColeCaL4**
Coleoptera	Carabidae	Lebiini small	**ColeCaLS**
Coleoptera	Chrysomelidae	*Arsipoda*	**ColeChAr**
Coleoptera	Chrysomelidae	*Cryptocephalus* blue	**ColeChCB**
Coleoptera	Chrysomelidae	*Cryptocephalus* bronze	**ColeChCZ**
Coleoptera	Chrysomelidae	*Paropsini*	**ColeChPa**
Coleoptera	Chrysomelidae	*Pyrgoides*	**ColeChPy**
Coleoptera	Chrysomelidae	*Peltoschema hamadryas*	**ColeChPh**
Coleoptera	Chrysomelidae	*Monolepta*	**ColeChMo**
Coleoptera	Cleridae		**ColeCl**
Coleoptera	Coccinellidae	*Coccinella L*	**ColeCocL**
Coleoptera	Coccinellidae	*Rhizobius* 6spot	**ColeCoR6**
Coleoptera	Coccinellidae	*Rhizobius*	**ColeCoR**
Coleoptera	Coccinellidae	*Rhizobius large red under*	**ColeCoRr**
Coleoptera	Coccinellidae	larva	**ColeCoL**
Coleoptera	Curculionidae	*Baris*	**ColeCuBa**
Coleoptera	Curculionidae	*Merimnetes*	**ColeCuMe**
Coleoptera	Curculionidae	*Poropterus*	**ColeCuPo**
Coleoptera	Curculionidae	*Scotasmus*	**ColeCuSc**
Coleoptera	Curculionidae	Tychiini	**ColeCuTy**
Coleoptera	Curculionidae	*medium*	**ColeCum**
Coleoptera	Erotylidae	*Thallis* blue	**ColeEr**
Coleoptera	Latridiidae	Corticariinae	**ColeLaCo**
Coleoptera	Phalacridae	*black*	**ColePh**
Coleoptera	Tenebrionidae	*Pteroheleus*	**ColeTe**
Coleoptera	Zopheridae		**ColeZo**
Coleoptera		*larva pink*	**ColeLarv**
Collembola	Entomobryidae		**CollEnt**

Collembola	Paronellidae		**CollPar**
Collembola	Sminthuridae	*Katianna* giant	**CollKati**
Diplopoda	Julidae		**DiplJuli**
Diplopoda	patterned		**Diplpatt**
Diplopoda	Polydesmida		**DiplPoy**
Diptera	Anisopodidae	Sylvicola	**DiptAnis**
Diptera	Chironomidae		**DiptChi**
Diptera	Chloropidae		**DiptChlo**
Diptera	Empididae		**DiptEmp**
Diptera	Phoridae		**DiptPhor**
Diptera	Sciaridae		**DiptSc**
Diptera	Tephritidae		**DiptTeph**
Hemiptera	Aphididae	Introduced sp.*	**HemiAph**
Hemiptera	Cicadellidae		**HemiCica**
Hemiptera	Coccidae		**HemiCocc**
Hemiptera	Eurymelidae	Eurymela	**HemiEury**
Hemiptera	Flatidae	*Siphanta acuta*	**HemiSiph**
Hemiptera	Lygaeidae	ant mimic	**HemiLygA**
Hemiptera	Lygaeidae		**HemiLygB**
Hemiptera	Miridae		**HemiMir**
Hemiptera	Pentatomidae		**HemiPent**
Hemiptera	Psyllidae		**HemiPsyl**
Hemiptera	Tingidae		**HemiTing**
Hymenoptera	Apidae	*Bombus terrestris**	**HymeBt**
Hymenoptera	Bethylidae		**HymeBeth**
Hymenoptera	Chalcidae		**HymeCh**
Hymenoptera	Formicidae	*Camponotus claripes*	**HymeFoCC**
Hymenoptera	Formicidae	*Camponotus consobrinus*	**HymeFoCS**
Hymenoptera	Formicidae	*Iridomyrmex*	**HymeFoIr**
Hymenoptera	Formicidae	*Iridomyrmex* male	**HymeFoIm**
Hymenoptera	Formicidae	*Iridomyrmex* queen	**HymeFoIq**
Hymenoptera	Formicidae	*Linepithema humile**	**HymeFoAA**
Hymenoptera	Formicidae	*Myrmecia* male	**HymeFoMy**
Hymenoptera	microwasp		**HymMicro**
Isopoda		*Porcellio* sp.*	**IsopPorc**
Lepidoptera	Carposinidae	moth	**LepiCarp**
Lepidoptera	Elachistidae	moth	**LepiEla**
Lepidoptera	Geometridae	larva L2	**LepiGeom**
Lepidoptera	Gracillariidae	moth	**LepiGr**
Lepidoptera	Lasiocampidae	larva L3	**LepiLasi**
Lepidoptera	Lymantriidae	larvaL3	**LepiLym**
Lepidoptera	Oecophoridae	moth	**LepiOeco**
Lepidoptera	Psychidae	*Cebysa leucotelus* moth	**LepiPsy**
Lepidoptera	Stathmopodidae	*moth*	**LepiStat**
Mollusca	Gastropoda		**MollGast**
Neuroptera	Coniopterygidae		**NeurConi**
Neuroptera	Hemerobiidae	*Micromus tasmaniae*	**NeurHem**
Opiliones	Phalangiidae		**OpilPhal**
Pseudoscorpion	Pseudoscorpion		**Pseu**
Psocoptera	Psocoptera		**Psoc**
Scorpionida	Bothriuridae		**ScorBoth**
Thysanoptera	Thripidae	black large	**ThysThB**
Thysanoptera	Thripidae		**ThysTh**
Thysanura	Lepismatidae		**ThynLe**

* introduced species.

APPENDIX VIII: BIRD PHOTO GALLERY[11]

Introduced Species



1. Laughing Kookaburra at Knocklofty Reserve.

2. Spotted Turtle Doves at Princess Park, Sandy Bay.

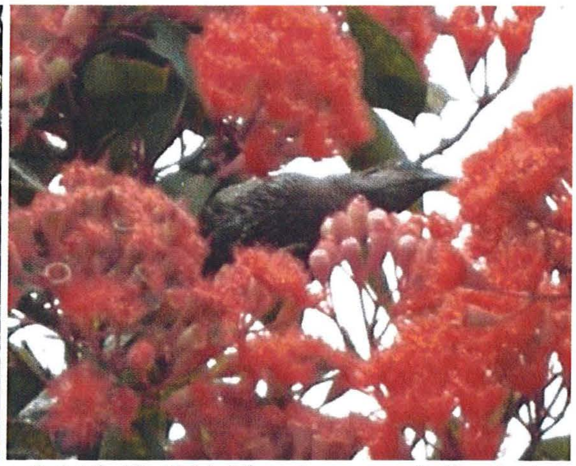
3. & 4. House Sparrows at Salamanca Square, Hobart.

5. Rock Doves, Eastern Rosellas and Noisy Miner at Queen's Domain grassland site.

[11] All bird photographs taken between February 8th and April 10th, 2007.

Honeyeaters

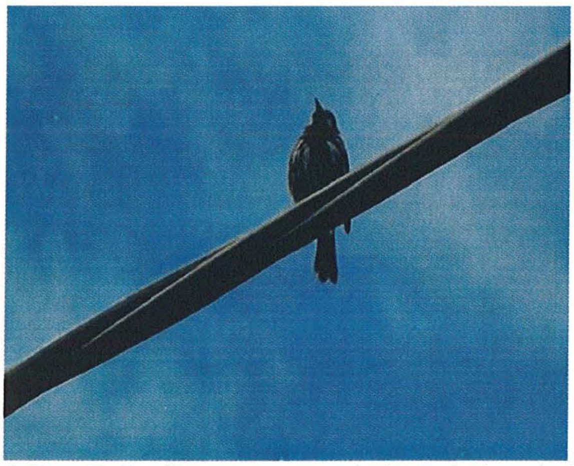
1. Yellow Wattlebird foraging on Eucalyptus, Queen's Domain grassland.



2. Little Wattlebird foraging on exotic Eucalyptus in garden, Sandy Bay.

3. Yellow-throated Honeyeater foraging on Eucalyptus, Knocklofty Reserve.

4. Crescent Honeyeater foraging on exotic plant in the Botanical Garden, Queen's Domain.



5. New Holland Honeyeater perched on telephone wire, border of Knocklofty Reserve.

6. Noisy Miner perched on sign, Queen's Domain.

Cockatoos and Rosellas


1. & 2. Eastern Rosellas perched in a dead tree and in the grass, respectively at the Queen's Domain.

3. Yellow-tailed Black Cockatoos, Queen's Domain.

4. Sulphur-crested Cockatoos in Eucalyptus, S. Bay.

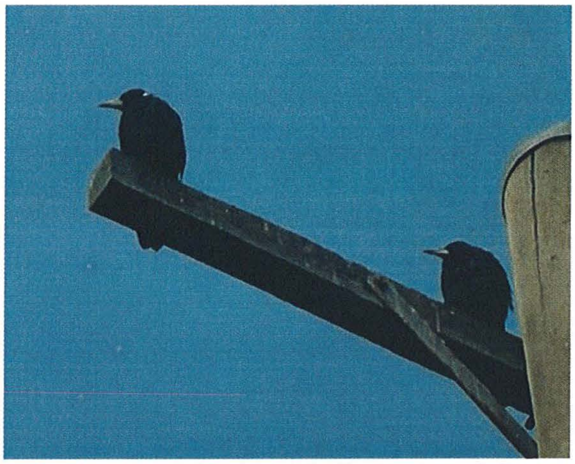
5. Sulphur-crested Cockatoos in Eucalyptus in front of Casino, Sandy Bay.

Thornbills, Robins, Butcherbirds, Corvids and Lapwings

1. Brown Thornbill in She-oak, Queen's Domain.

2. Scarlet Robin in Acacia spp., Queen's Domain.

3. Australian Magpie eating a mouse, Queen's Domain.



4. Australian Magpies on built structure, S. Bay.

5. Forest Ravens on University Campus, Sandy Bay.

6. Masked Lapwings on University Campus, S. Bay.